
Teacher professional development and gender in STEM

Preliminary thoughts and theoretical frameworks

STING

STING: STEM Teacher Training Innovation for Gender Balance

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Introduction

This paper summarises what our partners have told us about their previous experiences of teacher professional development and gender issues in STEM education. In general, there is plenty of experience within STING, together with useful resources and tools to apply in practice. The essential core of our activities should be devoted to bringing these experiences, resources and tools together in meaningful professional development that actually makes teachers' work more inclusive, effective and satisfying.

Projects contributing to this paper:

INSTEM (2012-2015) INSTEM is a Comenius network (2012 – 2015), which brings together the experience and learning of a wide range of projects in European Science and Mathematics education: <http://instem.tibs.at/>

PLEGMA (2011-2014) Host Organization: EUC Research Center (European University-Cyprus), Affiliated Partners: University of Cyprus, University of Patras

SMART Technology (2013-2014) <http://www.sentinus.co.uk/programmes/smart-technology/>
<http://www.northernireland.gov.uk/news-de-270314-stem-is-the>
<http://thethread.tv/video/90423133>

STIMULA (2010-). Stimulating Science and Technology competences through innovative means for teaching and learning: <http://stimula-project.eu/>

S-TEAM (2009-2012) Science-Teacher Education Advanced Methods: www.s-teamproject.eu

TWIST (2010 - 2012) Towards Women In Science and Technology. FP7 Framework Programme (Area Gender dimension of research): <http://www.the-twist-project.eu/en/>

Gender mainstreaming

In the context of teacher education policy development, gender mainstreaming ensures that teacher policies are designed with the knowledge that the society we live in is not gender-balanced, favouring one gender over the other, usually women taking the disadvantageous position, and that all the policy components address these gender equality issues (Mulugeta, 2012)¹

The above quote comes from a UNESCO training module developed in Africa, but it is important to remember that a range of gender issues have not yet been resolved, even in 'advanced' European countries. The STING project will contribute to achieving gender equity in the STEM classroom, but this work has wider implications for how we think about difference. Simplistic assumptions and stereotypes permeate our thinking about difference in all sorts of ways, and gender awareness is a prequel to further development, not just an end in itself.

We should also emphasise that gender awareness is not just about teachers and teaching techniques, but also extends to pupils themselves. With the rise of inquiry-based methods, and more active learning in general, the dynamics of classroom interaction have become increasingly important. Gender awareness amongst pupils should be part of their personal and social development, and whilst we are tasked with developing this awareness in STEM subjects, there are wider benefits to be obtained across whole schools and education systems.

What teachers say about gender

From previous projects in this area, we know quite a lot about these benefits, both in relation to gender awareness and in relation to teaching methods and attitudes:

We believe the main outcome of the project was accepting our own gender biases and starting to tackle them... (TWIST)

In order to start on this process, it is essential to use inquiry-based methods in teacher professional development, as the following quote illustrates:

Teachers thus seemed to join the program believing that the facilitators, as 'experts', had already developed a new body of knowledge that would be transferred to them...[but] in reflecting upon the ways their practice changed, the teachers, very explicitly stated that they had become more open and flexible (Plegma).

These quotes from two of our partners' earlier projects sum up the core principles of STING. In thinking about gender, there should be examination of assumptions, and in teacher professional development, or professional learning, there should be an extended process of reflection, design, testing, evaluation and implementation, in a continuous cycle, rather than

¹ Mulugeta, Emebet (2012) Gender Mainstreaming in Teacher Education Policy: A Training Module, UNESCO-IICBA, available at: http://www.eng.unesco-iicba.org/sites/default/files/Gender_Mainstreaming_in_Teacher_Education_Policy.pdf

one-off transfers of existing knowledge. On the other hand, teachers should not be expected to start from nowhere, but should be provided with starter materials or ideas as a basis for further development. It is also important that TPD courses have clear and logical structures to answer the “who, what, where, when, how” questions, which teachers and school heads will rightly want to ask about.

In addition to the projects that contributed to our preliminary survey, other projects examined in the INSTEM synthesis report (2014) have come to similar conclusions regarding teacher professional development (TPD). These are that:

- TPD should always start with a desire to improve outcomes for pupils.
- TPD should be collaborative, because collaboration enriches reflection and provides support for emerging ideas
- TPD should take place over an extended period and in multiple sessions, because ideas and groups take time to form and cohere
- TPD must be supported by senior management within and between schools
- TPD should be an extension of what has been learned in initial teacher education, but should also be based on current evidence and practices
- TPD should extend and challenge teachers, not just confirm their existing beliefs and practices.

It is also important to note that take-up of TPD opportunities is not always automatic, and that several conditions have to be fulfilled before project-based TPD will be accepted by schools, including the senior management support identified above. Given the short duration of STING, it is necessary to consider how TPD provided through the project can be continued after funding ends. Our best chance will be to provide high quality TPD that is relevant to teachers and which generates enough momentum to be self-sustaining afterwards.

Theoretical Framework – Gender

There are many theoretical positions on gender, but much work has already been done to synthesise these into something coherent enough for our project. From a practical point of view, the existing TWIST “One size fits all” booklet (TWIST, 2012) is a good starting point. We will, however, update material from the booklet in order to reflect current thinking. For example, we are increasingly seeing research indicating that math anxiety may be a barrier to girls thinking about science-based careers². We are also reminded by the TWIST project that:

The following section comes from the TWIST booklet “One Size Fits All” (2012) and provides some hints regarding a scientific view of gender differences.

Girls and boys differ from one another. Not only biologically, but also in the way they learn and behave. One difference in behaviour may derive from the effects of the hormones oxytocin and testosterone. Testosterone makes a male want to compete with others. When a boy wins, his testosterone levels rise. And they fall when he loses. Changes in hormone levels do not appear to be the same in girls. This suggests that competition could be a good motivator for boys to learn. Meanwhile, oxytocin has been found to affect social behaviour. Women have a higher level of this hormone, which stimulates them to establish relationships and to please others. And this suggests that girls may be more motivated when they work together on tasks or when a task is placed in a social context.

It is important to note that there will always be exceptions to the rule. Every child is different. Variations in the way children behave are found not only between the genders, but also within them. But if teachers are aware of the potential behavioural differences between boys and girls and know how to respond to them, the education of the whole class could be significantly more effective.

In addition, teachers should be aware of their own ways of learning. Just like their students, male and female teachers may have a more “boy-like” or “girl-like” way of behaving – which could make their teaching methods more suitable for either boys or girls. It is important to understand that your preferred teaching methods may not suit all your students. One size does not fit all.

The conclusion here is that difference is important, regardless of how it shows up in specific contexts. But first, we should remind ourselves why gender – and therefore difference – matters. The following section, by Dr Christine Hassenstab at NTNU, briefly sets out the history of feminist thought, which has, after many twists, led to our current project.

² <http://www.scienceguide.nl/201503/new-gender-gaps-in-education.aspx>

A Short History of Feminism

What we now might call “feminist» thought and action” has existed throughout history. It is sometimes in the forefront of political debate and, at other times, seems to be in abeyance; but it has always resurfaced in another form in another place at another time. We would do well to ask why this is the case? One answer is that patriarchy exists and has existed throughout time and the two phenomena react, adjust and react again to each other and to the demands of a human desire for fairness and equality.

Today, it is not uncommon to find references by feminist theorists and writers that reach into the ancient past. Antigone is a character in a play by the same name written by the Greek playwright Sophocles. Antigone defies the King’s command and buries her brother in accord with what she believes is divine law, outside the city walls. Antigone dies but she has defended the rights of the individual and her own conscience against those of society and social order.

During the Middle Ages, Christina de Pizan advocated for the rights of women in *The Book of the City of Ladies* (1405) and Mary Wollstonecraft, in 1792, argued for the moral and political equality of women in her treatise, *A Vindication of the Rights of Women*.

In the late 1800s and early 1900s, in the western world, the “first wave” of feminism was generated in the conjunction with the women’s suffrage movement in the USA and Europe, which itself was associated with worker’s rights movements originating in the Industrial Revolution and free speech movements. Women fought for the *de jure* right to vote and did so in a variety of ways. In England, suffragettes broke windows and heckled male politicians and when arrested, staged hunger strikes in jail. The methods used for force-feeding these women are akin to modern concepts of torture. Suffragette Emily Davison threw herself in front of a horse at the Epsom racecourse in 1913 and died. With the advent of World War I, women were advised that it wasn’t the “right” time to work for women’s rights but to work against Germany.

In the USA, in the first wave of feminism, Elizabeth Cady Stanton and Susan B. Anthony worked for women’s suffrage immediately after the Civil War. Prior to that, in 1848, at the Seneca Falls Convention, Lucretia Mott and others issued a *Declaration of Sentiments* on how women should be equal in society. By 1920, the 19th Amendment to the Constitution of the United States had been passed granting women the right to vote.

In 1914, Margaret Sanger began *The Woman Rebel* in the USA with the motto “No Gods, No Masters” on the masthead. She went on fight for the right to contraception, birth control and against unsafe abortion, founding *Planned Parenthood*. Her counterpart in Britain was Marie Stopes who authored the controversial book *Married Love* in 1918.

During World War II, women in many countries began to work in factories and social conventions changed even more rapidly through this experience. By the 1960s the “second wave” of feminism had emerged objecting to *de facto* inequality. The idealized family shown in the media of the 1950s was deconstructed when Betty Friedan wrote *The Feminine*

Mystique in 1963, motivated by Simone de Beauvoir's book, *The Second Sex*, written in 1943. Throughout the 1960s and into the 1970s, various hard fought battles culminated in the right to a safe abortion (Roe v. Wade, 1973), the Equal Pay Act of 1963 and the founding of the National Organization for Women (1966), among others. Despite this, ratification of the Equal Rights Amendment was delayed and ultimately defeated as reaction to women's liberation activated conservative religious groups in the USA and elsewhere.

After the second wave of feminism, feminist theory came under scrutiny within the cause itself. The feminist movement faced charges of being a middle-to-upper class white women's organization and twenty five years of soul searching began. Black American women led the way at about the same time as post-modernist theory also emerged.

During the 1980s and 1990s, various approaches to feminism were articulated. Luce Irigaray, Judith Butler and Seyla Benhabib worked on the representation of women in literature and politics. Irigaray studied with psychoanalyst Jacques Lacan and continues to address a range of philosophic and linguistic issues. She has been criticized as essentialist, but this is an on-going debate. Judith Butler is known for her theory of gender performativity in *Bodies that Matter: On the Discursive Limits of "Sex"*. This theory has been criticized by other feminists as not being concerned with real life and international (or global) feminism. Benhabib is best known as a philosopher and proponent of feminist critical theory. Catherine Mackinnon continues to write on feminist themes of pornography and sexual harassment in her jurisprudential writing.

The second wave of feminism increasingly provoked reactions by various fundamentalist religious groups, which grew into conservative political movements embracing politics as a means of enforcing the "true" and God-given role of women in society and which often employed women as their spokespeople. For example, tea party member Sarah Palin, one-time Governor of Alaska, learned her debating skills in high school as part of a Conservative Christian Fellowship.

In the 1990s in Olympia Washington, and Washington, DC the *Riot grrrl* movement began to provide a venue for female punk rock musicians. Events such as the off-Broadway show, the *Vagina Monologues* (1996), illustrated how the third wave of feminism expressed itself in society. As violence against women became a major problem in societies around the world, religion as the source of some of this violence also became an issue. In 2011, the group *Pussy Riot* staged a protest in Moscow's Cathedral of Christ the Savior to highlight the connections between the Orthodox leadership and Putin's election campaign. This use of guerilla performance to protest discrimination against women has led to their incarceration. With the gang-rape of a girl on a bus in Delhi in 2012, the issue of violence against women continues to have an international dimension.

The various emphases that feminists have are often dependent on the circumstances in which they find themselves. Feminists in relatively affluent countries can focus on issues that might not seem urgent to women in less affluent countries. But some issues remain constant and these are most often violence against women whether in the home or on a Delhi bus, the right to contraception and safe abortion, equal pay for equal work, and education. Feminists are often also supportive of the rights of Gay Lesbian Bisexual and Transgendered (GLBT) people around the world.



A rights-based perspective

The progress of women towards equal rights is not finished and is still contested in many geographical, social and economic situations. From the UNESCO training module mentioned above, we have this passage regarding the elimination of discrimination:

The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) is one of the comprehensive conventions addressing gender/women's issues. It was adopted in 1979 by the UN General Assembly. The CEDAW recognizes that discrimination against women violates the principles of equality of rights and respect for human dignity, and hinders women's participation in economic, social, cultural, and political life of their countries, thereby obstructing the development of their countries. In order to eliminate discrimination, the CEDAW obliges countries to incorporate the principles of equality and non-discrimination in their countries' constitutions and other relevant legislations. It further demands that all legal instruments that perpetuate discrimination be abolished.

Regarding education, Article 10 of the CEDAW lists out a number of measures that states need to take to ensure that women benefit equally and equitably at all levels of education, including the elimination of any stereotyped concept of the roles of men and women at all levels and in all forms of education. The reduction of female student drop-out rates and designing programs for girls and women who have left school prematurely are also stipulated. Article 11 further requires the rights to a free choice of employment and profession, promotion, job security, benefits, on- job and advanced training (Mulugeta, 2012).

This combination of historical perspective and scientific detail gives us a basis to act, but the next step is to look at teacher professional development (TPD) itself. What do we know already? The answer is that we know quite a lot about how it should work, but we also know from the experience of previous projects that implementing TPD in real-life school contexts is not easy. We also know that the best place to start is in initial teacher education, since this provides space for reflection often lacking in the working lives of teachers. Even more fundamentally, we need to introduce gender awareness into classroom activity, since future teachers are products of their own school experience (Harford & Gray, 2014).

We should also be careful about the careers dimension of gender and STEM. The continuously changing economic situation affects the labour market, and this in turn has a major effect on career choices, which are often more contingent than planned. EC concerns about the take up of science careers are important, but should not be used to pressure young people into any particular career path.

For STING, however, our plan requires us to run teacher professional development courses for in-service teachers, and this is what we need to focus upon in order to have a successful outcome.

Teacher professional Development³

Teacher professional development (TPD) evolves through thinking about teaching and teachers. Since metaphors form a major part of conceptual systems or “metaphorical schema” (Lakoff and Johnston, 1980, 1999), one way of categorising teachers is to use metaphors. The range of possible metaphors is extensive (Oxford et al, 1998) and cannot be fully explored here. To simplify matters, we discuss two of the most important metaphors, namely *teachers as technicians* and *teachers as pedagogical problem solvers*.

We use the first metaphor, *teachers as technicians*, to describe situations in which teaching is seen as delivering set curricula using approved methods and TPD is seen as upgrading teachers’ skills used in influencing student’s learning. The *teachers as technicians* metaphorical schema presents TPD as doing things *to* or *on* teachers and teaching as doing things *to* or *on* students. The metaphor of *teachers as pedagogical problem solvers* covers conceptions of TPD that are about doing things *together with* teachers and teaching as doing things *together with* students. To put it another way, using inquiry as an example, under this umbrella teacher educators and academics can see themselves as inquiring into ‘how to support teachers in inquiring into how to support their pupils in learning more often through inquiry (or perhaps, more accurately, a wider range of inquiry methods).’ (Smith and Hoveid, 2013, p.262). We recognize that these two ‘umbrella metaphors’ cannot cover the full range of metaphors for teaching but are sufficiently broad to serve our purpose.

Although TPD is likely to evolve differently depending on which metaphor is used, there are common elements. Both metaphors are compatible with a conception of TPD as *acquiring the set of knowledge- and skill- building activities that raise the capacity of teachers and administrators to respond to external demands and to engage in the improvement of practice and performance* (Elmore, 2002).

There is nothing here against the sharing of practices that have been successful in other contexts. The difference is that in the technician conception, they are handed down as ‘recipes’ whilst in the problem-solving scenario they are shared as possible solutions for professional consideration. Both are also compatible with TPD as a lifelong process, from initial teacher education to retirement (Villegas- Reimers, 2003). However, the differences are important.

The ‘problem solver’ metaphor relates to the need for TPD to move beyond simple achievement of subject knowledge and skills (Darling-Hammond & McLaughlin, 1995; Hewson, 2007; & Vescio, Ross, & Adams, 2008). This is based on an extended view of teacher learning and practice, in which perspectives have changed from knowledge to teaching practice, from one-shot training sessions to learning that takes place over time, and from individual to collaborative learning (Putnam & Borko, 2000; Borko, 2004; Watson & Manning, 2008). Traditional approaches (courses and workshops) fail to meet the

³ This section was written by Dr Colin Smith, who was a member of the S-TEAM project responsible for TPD in Scotland, and Bodil Svendsen at PLU-NTNU who is a practising teacher and researcher working on inquiry-based learning and TPD.

professional needs of science teachers (Bybee & Loucks-Horsley, 2000; Ostermeier, Prenzel, & Duit, 2010).

Furthermore, more traditional forms of TPD often treat teachers as isolated practitioners, thus limiting their exposure to the work of colleagues (Elmore, 2002). They also underplay the complexity of schooling (Ball and Frozani, 2007; Smith et al, 2013b) and, consequently, need to be more sensitive to the contexts in which teachers work and learn. Teacher learning is not a simple matter either and can be described as a complex system, involving systems within systems (Opfer & Pedder, 2011). Also, there is a shift towards collaborative inquiry approaches, often within schools, in which teachers work in partnerships and support and learn from each other. Professional learning communities may form when teachers work together with a focus on improved learning and teaching (Harris & Jones, 2010).

Based on the above, and on experience of developing approaches to supporting teachers in more inquiry-based practices within a European Union funded project (S-TEAM, 2013) called PISCES (Smith et al, 2013a, 2013b) and SUN⁴ Svendsen, 2012; Svendsen and Marion, 2013) we are suggesting that TPD can become professional learning through:

Teachers actively solving pedagogical problems that they identify themselves as relevant to the needs of their own students.

Instead of applying top-down prescriptions, the teachers themselves develop a focus on cultivating, and sharing, knowledge and skills about how to meet the learning needs of their students. For this process, teachers need conceptual tools to help them to make such decisions. TPD then becomes a matter of providing teachers with 'tools' to think about such questions as *What am I doing now and why? What might I do instead and why?* It is not a prescription of practice that treats teachers as technicians. It treats them as *professionals in situ* (Smith et al, 2013a, 2013b) – as people best placed to judge the needs of their own students and to seek ways to meet those needs.

This form of TPD - one in which models are provided to teachers so they have a language and matrix of concepts to describe, discuss and explain what they are doing, and what they might do instead, and to justify why this is worth trying - is more powerful than other forms, in that it embeds a wider repertoire of knowledge and action in teachers' practices. This repertoire is the basis of practitioner theories regarding what will support particular student groups with particular topics and for particular educational aims (Smith et al, 2013a, 2013b).

Sometimes, as in PISCES, participating teachers may work with individual student groups to solve pedagogical problems they have identified for those groups. The practices thus developed may be used in the future to solve similar problems. Support and collaboration, however, occurs through meeting over a period of time with each other and supporting academics or researchers. Or, as in SUN, they may come from the same school, or from other schools connected in science networks, and collaborate together (again with non-prescriptive support from academic researchers) in reflecting upon what they already do and what they might do to support each other in making those changes.

⁴ (<http://www.ntnu.no/skolelab/sun-prosjektet>)

Either way, teachers work together with a focus on meeting learning and teaching demands in their own contexts, and on generating new professional knowledge and may form what Bolam, McMahon, Stoll, Thomas, & Wallace (2005) describe as “professional learning communities”. These are communities where teachers, and ideally administrators, continuously seek and share learning, and act on that particular learning. Whether it involves intra or inter-school groups, supportive school leadership is necessary for professional learning communities to be effective (Robinson, Lloyd, & Rowe, 2008). School and local educational management can ask similar questions to teacher educators and teachers – For example, How do we, as school leaders, support our teachers in their inquiry into supporting their pupils into learning more often through inquiry (Figure 1)?

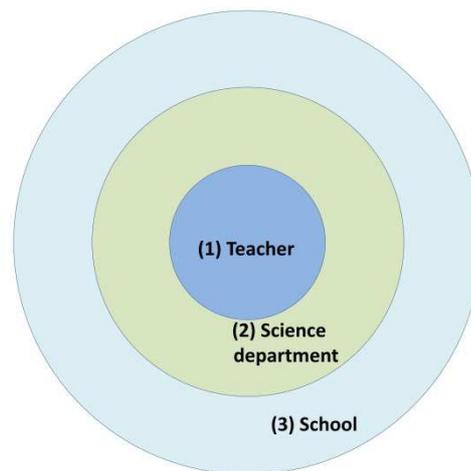


Figure 1: The bottom-up expansion model for TPD, illustrating different levels in school-based TPD (Svendsen & van Marion, 2013).

So, to sum up, it is possible for TPD

- (a) To move from top-down prescription of practice,
- (b) To support teachers in solving locally identified pedagogical problems
- (c) To provide conceptual tools that help them to analyse what they are doing in relation to those problems and what they might try instead, and
- (d) To move from a language of development to a language of learning and mutual support or co-operation.

Let us expand our metaphors into two models of how TPD might be implemented.

Two models of TPD

Loughran (2010) provides a description of the differences between teacher development and professional learning that we can use to further illustrate the distinction between the technician and pedagogical problem solving metaphors (see also Berry and Loughran, 2010) and how they might influence the evolution of TPD. Smith et al (2013b) adapted Loughran's model to present it as alternative models of how teachers might develop, or have imposed upon them, theories of practice or practitioner theory. This is further developed here (Table 1) to incorporate the experience of SUN, as well as PISCES.

Model 1 (*Practitioner Theory Developing Through Professional Development*) is a deficit perspective in which teachers lack skill to deal with changes in curricular policy, need to be shown something called 'best practice' by 'experts', and, by implication, are incapable of developing practitioner theory for themselves.

In contrast, in Model 2- (*Practitioner Theory Developing Through Professional Learning*) TPD occurs through processes of reflection, discussion and experiments in practice. Teachers, as professionals in situ, focus on developing practices appropriate to their aims and contexts.

It might be that model 1 is somewhat a caricature but, even so, when one of the authors (Smith) presented it to groups of teachers in Scotland and Latvia, they described it as being all too familiar. Model 2 differs from model 1, in that it begins with teachers' existing knowledge and beliefs (Verloop *et al.*, 2001), and in that the learning that follows is personally shaped by these beliefs. It is not a "reductive typology of professionalism" (Stronach et al, 2002) and is in line with conceptions of autonomy that emphasise that what one does emanates from the self, is self-authored, relates to one's own interests and involves choice in actions (Su and Reeve, 2011).

For the purposes of STING, then, we should be looking to Model 2 for inspiration and principles. Teachers are, more or less by definition, intelligent people who are capable of critical thinking and creativity, especially when given the time and space to *be* critical and creative. We should not, therefore, spend too much time and energy on refining materials as input to courses, nor should we develop new activities until we have explored those that already exist (e.g. in the "One Size Fits All" booklet developed by TWIST), and those that teachers may already be using.

On the other hand, there is room for an imaginative approach, and it would be particularly important, given our science and maths focus, to explore how teachers could detect and deal with mathematics anxiety and its relationship with gender (Miller & Bichsel, 2004). This is a problem that can affect teachers as much as pupils (Geist, 2010). It can be addressed in several ways, either through treating the symptoms of anxiety, for example through counselling or even breathing exercises, or by doing work in mathematics classes to improve pupils' depth of understanding.

Gender in research

A recent EC publication (Schiebinger, 2013) draws attention to various aspects of gender within research itself. We suggest that this aspect is as important as awareness of stereotypes and other gender biases in general, and can provide a number of benefits to STEM education. For one thing, the nature of gender stereotypes is itself something to be researched. The case study on gender and climate change (ibid. pp.79-86), for example, provides much material for discussion on the attribution of various behaviours to women and men.

This could be useful in making the topic of gender in science more prominent. Projects report that gender is not a major issue for pupils:

In general, the view of S&T [science and technology] by pupils in secondary schools in within Europe showed some common points. Gender influence was small; perceptions, interest and vocations related with S&T of male and female pupils were very homogeneous.

Bringing gender into the content of research will require teachers and schools to think about how socio-scientific issues can be accommodated within the limited time available for STEM education. In turn, we need to think about the influence of project interventions on school life and the curriculum. There is very little slack in most systems as regards teachers' time. Therefore, we need to find ways of merging our activities into existing teaching and learning activities, and existing teacher professional development courses or modules.

In the longer term, working with teachers and pupils on gender and research will promote the engagement of partners with the EC's *Responsible Research and Innovation* agenda, and in turn this will lead to increased possibilities within Horizon 2020. Reflecting on gender in research inevitably leads to reflection on the nature of research itself, and the reasons behind choices of research topic. A research project on ironing clothes might not have the same 'grandeur' as the Large Hadron Collider, but it might have a massive impact on domestic energy use. Similarly, there could be gender-based comparisons between the amount of effort spent on research on breast cancer versus that spent on other chronic diseases.

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