



Professional ethics and social responsibility: military work and peacebuilding

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Abstract

This paper investigates four questions related to ethical issues associated with the involvement of engineers and scientists in 'military work', including the influence of ethical values and beliefs, the role of gendered perspectives and moves beyond the purely technical. It fits strongly into a human (and planet)-centred systems perspective and extends my previous AI and Society papers on othering and narrative ethics, and ethics and social responsibility. It has two main contributions. The first involves an analysis of the literature through the application of different ethical theories and the application of gendered analysis to discussion of masculinities in engineering and the military. The second is a survey of scientists and engineers to investigate their opinions and experiences. The conclusions draw together the results of these two contributions to provide preliminary responses to the four questions and include a series of recommendations covering education and training, ethical approval of work not involving human participants or animals, the need for organisational support, approaches covering wider perspectives and the encouragement of individual ethical commitment.

Keywords Ethics · Social responsibility · Peace building · Military work · Gender · Survey

1 Introduction

1.1 Military work

This paper investigates four questions (see Sect. 1.3) associated with the involvement of engineers and scientists in 'military work'. This term is preferred to the more commonly used 'defence' work in recognition of the fact that in practice it is not purely related to defence. However, it should be noted that the choice of terminology is frequently determined by the values of the person using it, with supporters of military involvement of scientists and engineers more likely to use the term 'defence' and opponents 'military' work. These are crucial questions about the role of AI and other technologies and the type of society we want to use advanced technologies to create. This will be discussed in more detail when the questions are presented.

It is helpful to categorise military work, to clarify what we are discussing. Possible clarifications include both the type of work and the degree of military involvement (Hersh 2001; Roy 1989). Types of work include:

- Fundamental basic/theoretical research which is not linked to particular applications (though they are not excluded).
- Basic and applied research, with civilian and at most tenuous or distant military applications.
- Work on devices which support weapons use, but are not themselves weapons.
- Research on dual purpose military and civilian applications.
- Basic and applied research on militarily relevant topics.
- Research on defensive military hardware and software with no potential for killing.
- Research on offensive weapons designed for killing people and destroying property.
- Work for a firm with some military contracts.

Engineers and scientists who do military work may work at universities and technical schools that do military research

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(Hersh 2001) or be involved with military installations/bases and, suppliers including (Ullmann 1991):

- Firms that sell some of their usual products to the military.
- Specialised small and medium firms, for instance producing electronics and electromechanical components, that sell a significant proportion of their products to the military.
- Large companies with both military and nonmilitary divisions.
- Large military companies that almost exclusively produce military hardware, such as weapons, naval vessels and military aircraft.

1.2 National security: peacebuilding or weapons development

Unfortunately national security has tended to focus on military preparedness, including advanced weapons systems (Jackson 2011) rather than peacebuilding and resolving the problems that cause instability (Abbott et al. 2006). Engineers and scientists have been central to the development of weapons technologies which have transformed the nature of war. Despite the range of existing weapons from small arms to nuclear armed and powered submarines, scientists and engineers continue researching and developing new military systems. They also have significant involvement in the production and maintenance of existing weapons and military systems (Hersh 2015a).

Global military spending remains high at about \$1756 billion and an estimated 2.5% of global GDP in 2012 (Perlo-Freeman 2013; Perlo-Freeman et al. 2013) despite austerity measures in some countries. The number and scale of conflicts and the resulting deaths are slowly falling. However, there are now increasing numbers of protracted or recurring conflicts (Melvin 2012). The lack of success of nuclear and other weapons systems in keeping the peace and preventing human rights abuses is demonstrated by the 248 armed conflicts in 153 locations in 1945–2011 with an estimated 50–51 million violent deaths, including of civilians, in 1945–2000. National political decision-making, including genocide, starvation and deaths in prison camps and conflict, resulted in an estimated 214–226 million deaths in the twentieth century (Leitenberg 2001).

Understanding the causes of war and violent conflict can contribute to preventing them. One approach involves the author's three-component model of the causes of violent conflict with the components: (i) an issue of dispute, (ii) a context which favours instability and discourages peaceful settlement and (iii) a trigger event or circumstance. This

model and some of the main threats to global security are discussed in more detail in (Hersh 2013).

1.3 Research objectives

The paper aims to investigate the following questions:

1. The ethical issues associated with military work.
2. How ethical views and values influence professional engineering practice.
3. The extent to which awareness and practice of engineering ethics goes beyond professionalism and considers social, environmental and other impacts.
4. The influence of gendered perspectives on engineering.

It does this through its two main contributions. The first is a discussion of the issues related to military work using different analytical techniques (Sect. 2) and the application of gendered analysis to consideration of masculinities in engineering and the military (Sect. 3). The second is a survey of scientists and engineers to investigate their attitudes and experiences (Sects. 5, 6, 7). These two contributions are linked by a brief discussion of the actual and potential roles and responsibilities of engineers (Sect. 4). Conclusions drawing together the results of these two contributions to answer the research questions are presented in Sect. 8 and include recommendations (Sect. 8.1). The theoretical framework is different theories of ethics and the gendered and binary construction of engineering as a masculine domain focusing on the technical and professional and frequently excluding wider social, environmental and other considerations. This relates to work in AI and Society on gendered understandings of technology and its roles, e.g. (Barua and Barua 2012) and (Adam 1993).

This paper draws on and takes further my previous work in AI and Society on narrative ethics and othering (Hersh 2016) and values and social responsibility in science and technology (Hersh 2014). Different narratives are at the basis of the different constructions of the ethics of military work and are also an important theme in AI and Society, with recent examples including (Cunnean et al. 2019) and Adams (2019).

2 The ethics of preparation for war

2.1 Just war theory, defence, aggression and arms sales

Just war theory is still the most frequently used approach to discussing and justifying war (under limited circumstances), particularly in countries with a Christian ethos,

such as those in Europe and the USA. Justification of a particular war requires both its cause and its conduct to be just (Norman 1995). Technological advances are changing the nature of warfare and blurring the distinction between combatants and non-combatants required by the just war ethic (Norman 1995). According to United Nations Foundation (2008) estimates, 90% of those killed, injured and displaced in violent conflict are (civilian) women and children. 'Non-combatants', including politicians and engineers who have researched, developed and/or manufactured military technologies, are playing an increasing role in conflict and the resulting devastation. 'Combatants' may be child soldiers, conscripts or those lured into the military by the prospect of education and training and an escape from poverty.

Biological, chemical and nuclear weapons, landmines and some other weapons are considered inherently immoral, making it impossible for them to be used ethically. Designers and manufacturers are considered to share the moral responsibility for the 'resulting atrocities' (Fichtelberg 2006). This is recognised by conventions outlawing chemical and biological weapons and the Treaty on the Prohibition of Nuclear Weapons, which entered into force on 22 January 2021.

A country's historical record can give an idea of the justice of the aims to be achieved through war and the feasibility of weapons development serving a benign or even morally good purpose (Lackey 1989). The recent records of the USA and Europe show fabricated claims of weapons of mass destruction in Iraq and repeated bombing raids, including of Kosovo, Iraq and Syria, with largely economic and political motivation, but given humanitarian pretexts, indicating the unlikelihood of wars involving the USA and Europe being just.

Beliefs that scientific research for the military is a civic duty are based on just war theory and assumptions that governments are entitled to wage war if necessary to defend their citizens from aggression and that military research can reduce the destructiveness of war (Kemp 1994). However, 70–80% of all conflicts are now within not between states (sometimes with outside intervention) (Themnér and Wallenstein 2012), showing that the issue is very rarely defence against an outside aggressor. For instance, the UK remains committed to nuclear weapons and other high-tech weapons, despite its National Security Strategy stating that they are both not required and cannot deal with the actual national security risks (Bowen 2011).

The presence of advanced weapons systems may themselves pose a threat to those they are supposed to be protecting. For instance, convoys transporting nuclear weapons from Faslane to the maintenance plant in Burghfield two to eight times a year pass through or near several large cities. Collisions, break downs, and equipment failures have led to 180 safety incidents over the past 16 years, 43 in the last three years. The UK Ministry of Defence has admitted to

eight accidents between 1960 and 1991 and that in extreme circumstances the involvement of nuclear warheads in a multiple pile-up could produce lethal levels of radiation. More than three quarters of a million people live within 10 kilometres of a potential convey accident on the M8 motorway in Glasgow and up to 265 schools, 59 railway stations and 19 hospitals could be affected (ICAN 2016). Local authorities are both unprepared to deal with convoy accidents and not informed of convoy travel through their areas.

Most countries with a well-developed military capacity engage in the arms trade and a sizeable percentage of military production is exported. The 100 largest arms producers and military services companies, excluding those in China, had total sales worth \$410 billion in 2011 (Jackson 2013). There is limited regulation, due to the weakness of the Arms Trade Treaty, which came into force in 2014. Arms sales can support human rights abuses through direct use of the weapons and indicating international approval, thereby giving legitimacy and prestige (Williamson 1990) to governments which practice internal repression and torture. For instance, Syria modernised its forces prior to 2011 with imports of conventional weapons (Wezeman 2013).

Scientists and engineers considering military work should recognise that the ethical issues are not about military work to defend one's country, but the production of weapons which will be traded, including to conflict zones and countries with poor human rights records and which may be used in internal repression and which divert resource from resolving real problems and meeting human developmental and other needs (Herhsh 2015a).

Thus, the justification of military work and the use of high-tech weapons involves the creation of narratives which prioritise the needs of some groups over others and the use of technology in ways which are not human-centred. Unpacking what is happening in this type of scenario resonates with many of the issues of concern to AI and Society about the role of technology and its uses and abuses.

2.2 Other ethical issues: the human, environmental and other costs of war

War involves loss of life, injury, damage to and destruction of the natural environment and damage to property. For instance, violent deaths in the war in Iraq have been variously estimated as between 151,000 and 655,000 between March 2003 and June 2006 and more than three million people have been displaced as refugees or internally since 2003 (Perlo Freeman and Solmirano 2012). Ongoing armed conflict in Africa has had a serious impact on development, estimated at €18 billion per year or 15% of GDP and €284 billion since 1990. This sum could have been used to solve the problems of HIV and AIDS in Africa, provide education, clean water and sanitation or prevent tuberculosis and

malaria (Anon 2007). The production and export of arms can divert resources from solving the real international security threats of raw material scarcity, environmental degradation and unequal world resource distribution (Michalos 1989).

In considering the ethics of what they are doing, each arms exporting country and each engineer or scientist involved in military work should try to calculate the number of annual civilian deaths and injuries due to their weapons, as well as the illnesses that could have been prevented by spending the same amount on clean water, sanitation and other essential infrastructure rather than armaments (Bowen 2011).

Advanced military technologies, including drones and robots, may give an illusion of reducing the destructiveness of war, but may make longer wars politically acceptable. Killing and devastation at a distance facilitated by military technology is much easier physically and psychologically, as it removes the need to think about the humanity of the people being killed (Blue et al. 2013). A United Nations report considered that drones operated through computer screens have led to a 'playstation' attitude to killing (UN 2010). The development of 'soft kill' technologies has brought people involved in civil disobedience and non-combatants in war into the 'killing zone'. It has been suggested that the increasing use of high-tech devices for killing at a distance has made engineers and engineering technicians the new 'front-line soldiers' (Blue et al. 2013).

US drone strikes which have killed or injured children have been defended as necessary to protect 'our' children with statements such as 'the bottom line is: in the end, whose four year old gets killed?' (Waheed 2012). Killing four-year-olds will almost certainly lead to very high levels of anger and resentment, which can fuel conflict. In addition, protecting values or civilisation (one of the justifications sometimes given for just war) by killing or injuring four-year-olds cannot be justified.

Many scientists and engineers still give insufficient consideration to the ethical impacts and wider consequences of their work. A 1980s quote that army scientists are 'dedicated to science, not politics' and have an attitude of "Just leave me to my work and I'll produce for you" (Cole 1989) is unfortunately frequently still valid. The increasing potential and diversity of modern technology makes this even more worrying now than in the 1980s.

The significant military funding of universities, for instance in the UK, generally leads to reduced transparency (Hersh 2015a). The large-scale involvement of the military in education encourages acceptance of military activity and the militarisation and commercialisation of education (Stavrianakis 2009) and raises questions about why there is insufficient public funding. A Loughborough engineering student donated a prize funded by BAE Systems to the Campaign Against the Arms Trade, as 'university should be using its neutrality to promote ideals about the world we

wish to live in. Researching clean energy, improvements in healthcare and communications for all. Not more effective ways of wiping bearded folk off the planet' (Taylor 2007).

2.3 Diversification/arms conversion: the Lucas Aerospace Corporate Plan

Planning for alternative employment options which maintain high-level skills is required to enable a reduction in military work without affecting jobs in areas dependent on military bases and firms. One of the best known examples is the 'corporate plan' developed by the Lucas Aerospace Combine Shop Stewards Committee (LACSSC) based on the 'right to work on socially useful products' (Steward 1979). LACSSC involved 13 white and blue colour trade unions and represented the whole workforce across the 17 Lucas Aerospace factories. Half the firm's work involved military production. The corporate plan was motivated by the need to fight for jobs in a climate of economic recession and aimed to proactively develop a strategy for anticipated future redundancies as part of a positive alternative plan for the company. It was influenced by the 1974 UK Labour Party industrial strategy on transitional policies to social ownership and control.

Plan development took about a year and involved questionnaires to each plant, as well as outside experts (Steward 1979). The two main aims were protecting members' 'right to work' and including products which were 'socially useful to the community at large'. Other aims were using labour intensive methods which required existing high-technology skills rather than automation. The plan involved about 150 new products, including a road-rail vehicle, artificial limb control systems, aids for blind people, alternative energy technologies and hybrid power packs (Salisbury xxxx). Important features of the approach were involvement and discussion by the whole workforce of their future and linking employment to social needs (Steward 1979).

Unfortunately, management refused to diversify from aerospace work and 5000 jobs were lost by 1977. Lucas Aerospace no longer exists as a company. However, many of the plan products, including power packs and wind turbines, are now mainstream, indicating that diversification could probably have saved Lucas. The plan received worldwide support and charitable funding enabled LACSSC to set up centres on alternative products at two polytechnics which helped other workers develop their own plans (Salisbury xxxx).

Investigation of the effectiveness of arms conversion programmes in preventing unemployment and moving to civilian uses indicates that important success factors include sufficient advance planning, adequate resources, strong political support at national and local levels (Unite 2016), and a central role for all the workers, particularly through the trade unions. Examples of successful and unsuccessful diversification activities can be found in (STUC 2015; Unite 2016)

Overall success has been greater in the USA than Europe, partly due to the Base Realignment and Closure Act 1988, which requires five years advance warning of any closures and Federal government action to ensure early measures to maintain employment, and its implementation through the Office of Economic Alignment (STUC 2015; Unite 2016). Combination of the basic principles of the Lucas Plan with identified success factors and useful measures (STUC 2015; Unite 2016) is likely to have positive impacts.

Space constraints have prevented in depth discussion of the Lucas Plan. However, it is an excellent example of human-centred design and applications which take account of real needs. This again echoes an important theme in AI and Society, paralleling for instance (Brandt and Cernetic 1998; Rauner et al. 1988)

3 Social construction: engineering, masculinity and militarism

3.1 Binary social constructions

Engineering and the military have both been socially constructed in ways that are based on particular socially constructed views of masculinity. This leads to the exclusion or discomfort of many women. Application of gender analysis is helpful in unpacking and increasing understanding of both engineering and the military and the links between them. It is also useful in avoiding assumptions of male normativity and helping to provide wider perspectives on the actual and potential roles of engineers.

The term engineer was initially used for the military troops who built and operated military machinery (Tonso 1996). This is one of the factors that has led to a pervasive dominant masculinity in engineering with the typical engineer perceived as male (Wajcman 2000). It has been suggested that the gendered assumptions of military institutions have provided models for engineering and engineering education. In particular, engineering curricula are considered to combine 'technical training with cultural socialization that fuses hierarchy, discipline, loyalty and self-control' (Hacker 1989), with the later characteristics typical of the military. The construction of gender and sexuality affects work choices and experiences, with 'male work' such as engineering linked to male power and consequently higher status and better paid than women's work (Henwood 1998). Images of engineering as a masculine profession which is both tough, heavy and dirty (though inaccurate) and high-tech, corporate and for-profit play into gender stereotypes and the perception of being unsuitable for women (Pawley 2012; Powell et al. 2009).

While discussing the 'masculinisation' of engineering, it is important to recognise that the acting out of masculinity

is affected by culture and has changed over time. Thus, there are both common factors and very significant differences in the understanding and embodiment of masculinity in different cultures. This makes it more appropriate to talk of masculinities than masculinity (Hearn 1996).

Engineering frequently has a binary perspective, including people or technology focussed, social or technical and detached objectivity or emotional connectedness. These duals have strong gender associations, with technology focus, technical and detached objectivity considered male and people focus, social and emotional connectedness female. Engineers are assumed to be responsible for any deficiencies in their technical work, but not for the outcomes of this work (Blue et al. 2013) and its social and environmental impacts. This 'masculinist' ideology based on the construction and assumed superiority of masculine characteristics (Blue et al. 2013) has also contributed to engineering gatekeeping and the exclusion of minority groups and individuals (Seymour and Hewitt 1997).

3.2 Women engineers in the workplace

There has been a tendency to construct and position women engineers as different from both men and other women. Differences from other women include being 'exceptional', strong, determined, 'high flyers', who, unlike other women, are not discouraged (Henwood 1998) by all the difficulties of being a woman engineer in a male environment. The construction of women in engineering as 'exceptional' implies that engineering is 'men's work' for which most women are unsuited, and is therefore a barrier to their participation. It also does not allow women engineers to be average or fail and has contributed to the limited approaches and unsuccessful outcomes of equal opportunity policies (Henwood 1998).

Most studies agree that women engineers position themselves as career-oriented, qualified professionals, who are intellectually engaged, confident and passionate about their work (Bastalich et al. 2007; Jorgenson 2002) and, if they have children, good mothers worried about conflicts between work and family. It is unlikely that research on male engineers would have investigated or identified concerns about their role as fathers. Women engineers also want to be considered as individuals rather than a homogenous group (Jorgenson 2002).

Women engineers have taken two main approaches to their minority status in a profession constructed as male: (i) being 'just as good' as men, (ii) emphasising differences and the impacts of engineering work cultures (Bastalich et al. 2007). The first group associated success with competence, masculinity and rationality and femininity with emotionality and considered engineering suited to independent self-confident people. They rejected gender inequality, were unaware

of sexism and gender discrimination and considered that men and women had equal opportunities (Cockburn 1985; Faulkner 2000; Morgan 2000). They had no problems with male dominated workplace cultures and actively fit in to show they did not require special treatment (Bastalich et al. 2007; Jorgenson 2002; Powell et al. 2009). However, this may have been a means of positioning themselves as qualified engineers and part of an acceptance strategy in a context favouring male interests and perspectives (Jorgenson 2002).

The second group focused on the different qualities they could bring as women rather than proving themselves in male terms and had become engineers as a result of their maths and science ability and interest in engineering. They experienced difficulties with engineering culture and missed the presence of other women, leading to them leaving or considering leaving the profession. However, both sameness and difference narratives detract attention from women engineers' generally agreed competence (Bastalich et al. 2007) and draw attention to their minority and contested status.

This discussion of women and how they position themselves in engineering parallels that in AI and Society on the gendering of computing and computers (Barua and Barua 2012; Mackinnon et al. 1993). The continuation of this scheme in the discussion of gender and engineering cultures in the following section again parallels discussion in AI and society on the gendering of computing culture and (Truckenbrod 1993) and the gendering of technology (Adams 2019).

3.3 Engineering culture and masculinity

'Tinkering' with components and machines frequently given a female persona has been found to be an important part of engineering culture (McIlwee and Robinson 1992). It has contributed to the development of a symbolic relationship between masculinity and technology which continues to have a significant role in the exclusion of women from science and engineering (Holth and Mellström 2011). Men use interactions and relationships with machines to create gendered spaces in various cultures, including Sweden and Malaysia. Women are both excluded and transformed into machines given characteristics men would like in a partner (Mellström 2004) and with which they have heterosexual 'technoerotic' and platonic relationships. Thus 'tinkering' with 'female' machines has a major role in the lives of male engineers and acts to reproduce normative heterosexuality and gendered differences (Holth and Mellström 2011).

The 'tinkering' culture remains largely male only and is partly responsible for continuing assumptions that mechanical abilities are second nature to men, but not women. The passing on of gendered knowledge, a close paternal relationship and learning about technology from their fathers are important for many male engineers. This lack of experience has been found to negatively affect the career prospects of

women who had not 'grown up tinkering' and did not share the 'obsession' unless active measures were taken to change this (McIlwee and Robinson 1992). However, knowledge about technology, though not necessarily the 'tinkering' culture, is sometimes now also passed on to daughters (Holth and Mellström 2011), including by the increasing, but small proportion of women engineers.

Engineering workplace cultures are still based on narrow masculine norms and intolerant of diversity (Bastalich et al. 2007). There are frequently pressures to confirm, organisationally powerful male networks, the generic use of 'he', heteronormative and sexualised culture and conversation dominated by male interests and sometimes a lack of sanctions against offensive 'humour' (Faulkner 2009; Holth and Mellström 2011). Many women experience difficulties with this masculine culture (Evetts 1998; Skaggs 2013) and the values, systems and performance criteria established by men for men (Powell et al. 2009). The likelihood of discomfort may lead them to decide against science, engineering and technology careers (Glover et al. 1996) or change career after graduation (Skaggs 2013).

The adaptation of engineering culture by women engineers may require an impossible and unhealthy balancing act. They need to construct and manage an appropriate gender identity, possibly by distancing themselves from other women, accepting traditional stereotypes and male culture and ignoring sexist behaviour by defining it as exceptional (Dryburgh 1999; Jorgenson 2002). Women engineering students have been found to frequently question why they continue to be integrated academically, but not into engineering networks (Skaggs 2013). Both women and men have work focused, positive and respectful engineering workplace interactions. However, male–female interactions tend to be more formal and lack the banter and familiarity found between men (Holth and Mellström 2011).

3.4 Masculinity in the military and engineering

Militaries have also been recognised as playing an important role in shaping masculinity in broader society (Barrett 1996; Woodward 2000). Despite increasing numbers of women, the overwhelming majority of the 20 million military globally are male (Connell 2000). Military training leads to male socialisation into a violent concept of masculinity (Cock 1992) with combat its ultimate test (Cock 1992). Women have generally been excluded from combat (Carreira 2006; Heineken 2000) due to their perceived lack of strength (Heineken 2000) and perceived responsibility for children, whereas men's perceived roles include defending the country, women and children (Mankayi 2006).

Military culture, socialisation and identity involve a particular type of hegemonic masculinity (Barrett 1996) which, by definition, excludes women. Aggression, violence and

macho behaviours are combined with a caring supportive masculinity required for camaraderie and the effective teamwork necessary for a functioning 'killing machine' (Green et al. 2010). The male, strongly heterosexual warrior hero is still the key representative of military masculinity and used in the construction of national security (Lomsky-Feder and Rapoport 2003; Woodward 2000). However, 'heroic' risky behaviour which endangers the team is disapproved of (Green et al. 2010).

Successful soldiers are 'one of the boys' and engage in banter to become part of the in-group (Green et al. 2010). Humour and banter have been found to be important in constructing and consolidating gendered identities (Kehily and Nayak 1997). However, this type of masculine in-group is even more difficult for women to break into and become accepted by than engineering networks. Women are likely to lack the close 'buddies' who are important for survival, particularly in combat, and this is probably one of the factors that permits high levels of sexual harassment, lack of respect and actual violence against women in the military.

Women's presence in the military leads to paradigm discomfort and rejection due to the contradiction between 'defending' the country and traditional discourses of women needing to be protected (Mankayi 2006). Agency by women, including active sexuality, challenges double standards and constructions of military masculinity based on domination. The most horrifying example of this is the use of rape as a weapon of war and 'reward' to male soldiers, which may be encouraged by some male leaders as part of military socialisation e.g. (Neill 2000). Rape was finally recognised as a war crime in 2000 (Neill 2000). Women military are also at risk of sexual harassment and rape and sometimes even murder by their male colleagues and conspiracies of silence by their superiors (Enloe 2004). Sexual harassment is prevalent and a lack of respect for women's authority, rank and commands even more so (Heineken 2000; Sedibe 2000).

Thus, the links between the gendering of engineering and the military contribute to linking the two and restricting engineering practice. In particular, this leads to a limited focus which ignores wider issues related to caring and the needs of minority groups and the environment.

There is increasing, but still limited, awareness of wider gender possibilities and rejection of binary gender. Feminists and queer theorists are challenging gender dualisms (Lorber 2000) as hierarchical and resulting in gender inequalities and stereotypes to which real people do not conform. Gender binaries may lead to binaries in other areas, particularly those that are strongly gendered, such as science and engineering (Faulkner 2000). Binary opposition also limits possibilities by structuring the world as mutually exclusive opposites (Massey 1995). Moves beyond binary gender could lead to a welcome deconstruction and reconstruction of engineering.

4 The role and responsibility of engineers

Engineers and engineering have a very significant impact on society. The quote at the end of the Sect. 2 highlights the issues of the purpose of engineering and the vision of future society engineers should be trying to construct. Sects. 2 and 3 have discussed the involvement of engineers in the military and the masculinisation of the profession which leads to a focus on the technical at the expense of wider considerations of the environmental, social and other impacts of engineering.

However, the construction of engineering is changing. There is increasing understanding of the need to consider uncertainties in both the problem and potential solutions rather than assuming the appropriateness of current technologies for solving significant challenges (Nieusma and Tang 2012). There is increasing integration of the social and technical and attention to social justice concerns in engineering education, at least partly in response to accreditation requirements (Nieusma 2013). This gives exciting and creative possibilities for projects for implementing social justice which take account of the wider context (Nieusma and Tan 2012), consider local requirements and fully involve local end-users. More than a century ago Tesla (1905) proposed the use of technologies for transmitting information and electrical energy as a means of furthering peace in the world. However, the potential of technology in this area has not yet been achieved. This transformation needs to encompass a greater diversity of engineers, as well as applications that contribute to peacebuilding.

However, current values of material advances for human benefit and the lack of consideration of who will benefit have resulted in a tacit assumption of engineering design for (non-disabled) white men (Downey 2012) by middle class (non-disabled, white) men (Oldenzil 1999). This has also led to the normalisation of a particular type of engineering which does not challenge dominant values, supports the industrial-military complex and can exacerbate social injustice, particularly in developmental contexts (Downey 2012). There are also examples of participatory approaches to engineering projects to meet real needs. For instance, the Program of Rehabilitation Organised by Disabled Youth of Western Mexico (PROJIMO) is organised and run by disabled young people and takes a participatory approach to design and involves users as co-designers of assistive technologies, which are tailored to their cultural and physical context (Werner and PROJIMO 1998). Members also work to prevent violence, challenge social attitudes to disability and create jobs for disabled youth.

These issues are investigated and considered further through a survey of engineers, their attitudes, experiences

and education and training, which is presented in Sects. 5, 6 and 7.

5 Methodology

A five-section questionnaire was used to investigate the experiences and attitudes of scientists and engineers. Section A covered career based information, such as type of employer, whether working, studying or unemployed, and years of experience, to try to ensure a diverse sample and enable statistical correlation to be carried out (if sufficient results were obtained). Section B investigated participants' views on ethical issues, including the ethical factors considered in different types of decision-making, whether certain types of activities should require ethical approval and the most important ethical issues in professional and personal contexts, as well as changes over time. Section C considered ethical issues in employment, including participants' views on employment involving certain types of weapons systems and types of employment they would like and avoid on ethical grounds, as well as changes over time, and experiences of ethical dilemmas in their careers. Section D investigated participants' education and training in ethical issues, both as part of their original qualification and in subsequent employment. The final section provided opportunities for further comments and suggestions. The questionnaire obtained a mixture of quantitative and qualitative data, often in the form of multiple choice or rating questions followed by opportunities to comment on and explain the answers.

Ethical approval was obtained from the Ethics Committee of the College of Science and Engineering of the University of Glasgow. The questionnaire was available for anonymous completion online or as a WORD file. Information about the questionnaire was circulated to the engineering or engineering and science departments, schools, colleges or faculties of many UK universities with a request to send it to all their staff. It was also posted to email lists and sent to my contacts and publicised using social media.

6 Results

6.1 Participant overview

Only 15 responses were received despite fairly wide circulation and it is recognised that these respondents may not represent the whole engineering and scientific communities. Although a much larger number of fully representative responses would have been desirable, it is legitimate to analyse the opinions and experiences of a small group in a larger population, particularly when there is little research

on the topic and group (as is the case here). However, it is important to avoid inaccurate claims of representativeness.

Two-thirds worked at universities and 13% in industry. The others worked as an author and independent consultant, both in industry and universities and in honorary positions. Just over half (53%) were employed and a third retired. The areas worked in were very diverse and included computer science, environmental communication, chromatography, fuel poverty, human genetics, aerospace and science-religion dialogue. The overwhelming majority (87%) were male, as is typical of the sector, with no non-binary representation. 60% were from different countries in Europe (France, Ireland, Poland, Romania, Scotland, UK), with individuals from Canada, Indonesia, Saudi Arabia, South Africa and multiple countries. Participants were mainly very experienced, with two-thirds having worked more than 21 years, 27% 11–20 years and 7% two to five years. Most of them worked in large organisations, with 40% in organisations having 201–1000 workers and 40% in organisations with more than 1000 workers.

6.2 Views on ethical issues

Participants considered ethical factors to be important in decision-making on choice of career and decisions about whether to participate in particular activities, with average scores ranging from 4.1 for decisions on participation in a particular project to 4.6 for choice of career. Their views were also fairly stable over time, with 80% considering they would have given the same responses five years ago and 73% 10 years ago (with 7% too young then), and two-thirds giving the same responses 20 years ago and one third unsure.

Currently, in most organisations, an ethical approval process is only required for projects involving human participants and animals. Participants were generally strongly in favour of the need for ethical approval being extended to projects involving the development of (i) technologies or materials intended or likely to be used as weapons, (ii) the development of toxic chemical or biological materials, (iii) the development or use of materials likely to have a negative effect on human health or the environment and (iv) developments likely to have a negative effect on human society. In each case, two-thirds of participants very definitely supported this extension, 7–13% supported it and 7–20% possibly supported it. However, the issue of ethical review of research not involving human participants or animals and the extension of ethical approval to these areas seems not to have been considered previously in the literature.

Reasons for their views included recognition that 'most work does impact upon society and the planet at large'; the need that 'innovations are subjected to agreed ethical performance and not accepted ... purely on the basis of technical contribution' due to 'the speed variability and complexity of

technological innovations and their impact on human dimensions and the animal kingdom'; the need for ethical review of projects 'which can influence any aspect of life'; and the need to 'protect the human and environment' in the case of projects that 'can give harm to human and environment'. These views illustrate participants moving beyond the binary divide and taking responsibility for the outcomes of their work (Blue et al. 2013). However, caution was expressed in terms of the ability of university ethics committees to make good decisions in line with criticisms in the literature (Dyck and Allen 2013) and a suggestion that 'ethics ... is sometimes taken too far'. There was also recognition that the applications of research were not always clear and that 'tech might seem mundane but could be used in weapons'.

6.3 Ethical issues in employment

Participants provided a variety of ethical factors that affected important decisions, though one participant did not respond due to lack of 'understand[ing] of what 'ethics' actually means in my professional capacity'. Personal and scientific integrity was considered important in all the proposed situations in line with the literature (Loui 2005). In the case of job choice, participants were additionally concerned about the ethics and culture of the employing organisation, avoiding harm in line with the principle of non-maleficence (Hersh 2015b), e.g. warfare, and particular issues related to the use of genetic and personal data, climate change, poverty and rights. Thus, participants were concerned about the real threats to global security, including growing militarism, climate change and global poverty (Abbott et al. 2006; ORG 2006). In the case of choices to work on a particular project, the ethical issues considered included the need for the project, its funding source, public safety, intellectual property and ethical conflicts with the project values. Ethical factors which affected decisions to provide advice or consultancy included the ability to provide the service, confidentiality, privacy, avoiding conflicts of interest, the funding source and the need for the advice or consultancy. Ethical factors which would affect day-to-day professional decision-making included work ethics, professionalism, well being, avoiding harm, public safety, group development, mutual support, honesty and freedom to exercise judgement. Thus, both day-to-day decision-making and choices to work on a particular project combined considerations of professionalism with wider concerns, thereby countering the binary divide and integrating technical/professional and social justice concerns (Nieusma 2013). Wider issues of the need for the project and its values were considered in the case of choices to work on a particular project, but less relevant in day-to-day decisions.

Participants' reasons for their ethical stances on these issues were based on personal ethical statements in several cases. They included coming from 'a faith tradition which

helps me make sense of ethics at a personal and institutional level'; choosing 'not to take projects and jobs based on their connection to military application'; 'personal integrity is very important'; and 'I would not be comfortable using genetic data to inform insurance policies for example'.

A range of ethical issues were presented as being important in a professional context, with honesty the most frequently cited and one participant considering the area 'complicated'. The importance of honesty parallels the literature on honesty and integrity being given the same importance by engineering students as technical competence (Loui 2005). Other important ethical issues covered professional, relationship and wider issues, though some issues fit into more than one of these categories. Professional issues included intellectual property rights, sharing scientific information and research ideas, non-disclosure agreements, dynamic responsibility and returning results to patients. Relationship issues included fair treatment of staff and avoiding ethical conflicts with employers. Wider issues included the bias from only sharing positive analysis and results, funding allocations, benefits to participants not just the academic, and (gender and race) equality and diversity. Thus, their concerns could again be divided into professional ethics and wider ethical issues relating to opening up engineering beyond middle class (non-disabled, white) men (Oldenziel 1999).

Honesty was again the most frequently cited important ethical issue in a personal context, followed by integrity. Other issues covered relationships and personal ethics. Relationship issues included avoiding conflicts, care and emotional support for colleagues and mutual respect and recognition. Issues of this type are in line with the ethics of care (Gilligan 1982). Issues related to personal ethics included sharing information about financial and socioeconomic status, personal conduct, deciding whether to stay in research or move into industry, balancing personal standards, the public's need to know and commercial secrecy, and faith motivated ethics.

87% of participants responded to a number of open-ended questions on their attitudes to particular types of military employment (see Table 1). Two participants, a university assistant professor and a retired information systems manager, both from outside Europe, did not respond to any of these questions.

One participant was willing to participate in all types of military research and development and maintenance as long as this was 'in agreement with the ethical policy' in line with rule based approaches to ethics (Hersh 2015b) without stating which ethical policy or how they would evaluate its adequacy. Another (reported in the 'other' category) indicated tradeoffs between, for instance, money and responsibility and high expertise and (selective) scholarship, without indicating the choices they would make. Comments indicating opposition to particular types of

Table 1 Participants' attitudes to participating in different types of military R&D and maintenance work

	Research and Development (%)						Maintenance (%)					
	Yes	Condit	Restrict	Other	Unsure	No	Yes	Condit	Restrict	Other	Unsure	No
Small arms	7	13	20	7	7	33	13	7	7	7	0	53
Military aircraft	7	7	13	7	0	53	27	7	0	7	0	47
Submarines	7	7	33	7	0	33	20	7	0	7	0	53
Data mining systems for surveillance	13	13	0	13	0	53	7	7	0	7	0	60
Cluster bombs and land mines	0	13	7	7	0	60	7	7	0	7	0	67
Protective clothing for military context	27	7	20	13	0	27	13	7	0	7	7	47
Nuclear weapons	7	7	7	7	0	60	7	7	7	7	0	60
Cyber weapons	7	7	20	7	0	47	7	7	7	7	7	60

Condit = under certain conditions, Restrict = in restricted circumstances

military work included 'These technologies should be abolished. Encourage anyone considering such a career to do something useful with their lives.'; 'These are instruments of unnecessary killing.' This links to and goes beyond just war rejection as inherently immoral, of indiscriminate and 'cruel' weapons, such as nuclear weapons and landmines (Fichtelberg 2006). Other concerns about military work included 'I have a real problem with the levels of surveillance and I am totally against this aspect of our society'; and 'The development of any military hardware or technology has to be put into the context of escalating the arms race ... All of these technologies are developed at the expense of more socially beneficial expenditures. This is in line with the literature on diversion of resources by military work from solving real problems (Anon 2007; Michalos 1989). The military industrial complex is a real problem both in terms of the threats of increased conflict, and the loss of opportunities to use the human and financial resources for socially progressive purposes'. One participant referred to the temptations (of surveillance work) as the 'shiny cup syndrome' with scientists 'preoccupied with the technical challenges'. This is in line with the literature on the binary focus on technical work, but not its outcomes (Blue et al. 2013).

Comments supporting (very) restricted work in these areas include 'As one of the worst wars is going in Syria, I would feel this is unethical but the RND is needed so that engineers and scientists are aware the harmful part of these weapons and eventually propose something to the United nations about these weapons.'; 'Every country has its own right to protect its country so there have to be RND for every aspect of military. Without RND, one country can damage the environment and human in worst ways.' This seems to be in accordance with just war theory (Norman 1995). Other comments supportive of limited military work included 'R&D into making small arms easier to conceal and more lethal ... will only increase the risk of intentional and unintentional misuse. R&D into features

that will make small arms safer ... should be encouraged.' Though initially the participant seemed aware of the wider implications of small arms development, the comment about safety possibly indicates a separation and focus on technical rather than social, environmental and other wider concerns (Blue et al. 2003). Another participant is aware of the wider issues (Nieusma and Tang 2012), but still possibly trying to find some areas in which they can work. 'R&D Employment in this area remains for the most part ethically challenging .. There are few socially beneficial areas of R&D here.'

Two-thirds of participants would have given the same replies 10 years ago and 47% 20 years ago. Reasons for the changes included the increasing importance of cyber technologies, rejection of nuclear power and now believing 'we can move forward with renewable and safer energy sources', 'age and cumulative experience' and changes in worldview with recognition that 'all the western countries have the financial power in developing weapons (through technology) and destroying human lives for the sake of economy and power gain'. To some extent, this change in perspective shows increasing awareness of the underlying causes of conflict (Abbott et al. 2006) and the consequent need to avoid activities which contribute to them.

Ethical issues had affected the career choices of the overwhelming majority of participants (87%). Particular concerns related to doing work that was (socially) useful, avoiding involvement with 'harmful technology' and trying to 'benefit humanity and the planet, not destroy it' in line with the principles of beneficence and non-maleficence (Hersh 2015b). One participant considered that university work had fewer ethical issues than industry or government. Two participants explicitly avoided and declined military work and, in one case, changed jobs as a result. One participant worked for the 'defence industry' and another was (initially) a 'military engineer' and 'was confronted with ethical issues affecting my choice of career'. 80% of participants would avoid particular types of employment and two-thirds had

preferred types of employment on ethical grounds. The types of employment most frequently avoided included military or weapons work, but also covered genetic data in insurance, fossil fuels, nuclear power, government, US companies and 'areas that did not align closely with my values'. This illustrates participants challenging the normalisation of engineering which supports dominant values and the industrial–military complex (Downey 2012). However, in the case of having to make choices about providing for their family or avoiding choices counter to their values, this respondent would choose their family. General comments on preferred areas of employment included 'avoiding harm' and 'using technology beneficial to well being'. The most frequently cited specific area was education/academia/university. Other specific areas included NGOs and pastoral care, health care, food, environmental sciences, pharmaceuticals, renewable energy and sustainable agriculture and regulation of firms.

The overwhelming majority of participants (93%) had experienced ethical dilemmas. A third of the participants experienced such dilemmas a few times a year, 7% once a year and the others had experienced them once or a few times. The frequency of dilemmas indicates the importance of both engineering ethics education and support. (See Sect. 6.4 for discussion of ethics education.) Dilemmas covered a wide range of issues. They included refusing jobs involving ethical compromises or which were professionally too challenging. In one case involving nuclear power, the participant was threatened with dismissal. One participant faced dilemmas about accepting corporate funding each year and resolved them using corporate social investment to 'do beneficial work'. Other dilemmas related to bad practice and possible illegality. One case involved an investigation into possible contamination of a pharmaceutical product with a small risk to consumers being ended while the participant was on holiday, probably without further action, and their lab books being 'misplaced'. Another involved a principal researcher misappropriating co-workers' ideas and 'green-washing' a power plant. In the last two cases, the participant left the organisations (soon afterwards), in the power plant case to allow them to expose their former employer's bad practice. Another respondent set up and promoted a social mentoring programme to overcome institutional barriers to the employment, retention and development of colleagues from minority and disadvantaged groups, thereby working to reverse the exclusion of minority groups and individuals (Seymour and Hewitt 1997).

6.4 Education and training on ethical issues

The university or vocational course of just over half the participants (53%) involved education and/or training in ethical issues, that of a third did not and 7% were unsure. There were a number of different modes of delivery, with a

combination of separate course modules and integration into other teaching the most common. Other options included a separate course module, integration into other course modules and occasional workshops. The amount of time involved varied greatly from half or one day to 5 or 10%. There did not seem to be any standardisation in the topics covered. Some courses or training covered issues such as data protection, equality, obtaining ethical approval and ethics for engineers. Others were more specific and covered human-centred design, technology and society, medical ethics, including patient communications, confidentiality of patient records and ethical issues in developing health IT systems and use of animals in science. The overwhelming majority (88%) of those with ethics education considered it useful. Positive further comments included ethics making 'students and researchers reflect not just on their lives, but also on their role and contributions to society, beyond the straitjacket of institutional structures and regulations' and 'teaching medical students how to protect patient information. We also teach designer and developer of health IT system to be aware of ethical issues during RND stage.' These comments parallel the literature on the increasing importance of integrating the social and technical and the importance of social justice in engineering education (Nieusma 2013) and engineering ethics involving 'social and global stewardship' (Loui 2005). Critical comments included education being 'procedural [rather] than stimulating engagement' and having worked in an unethical political regime which lacked interest in education and training on ethical issues. The first comment parallels concerns in the literature that engineering ethics education is superficial (Newberry 2004).

A third of participants had participated in subsequent education or training on ethical issues and 40% had not, with the remainder not responding. For those who had, this was a matter of choice rather than an employer requirement, though in one case it was also required for professional registration. The amount of time involved again varied greatly from half a day to 10%, with one participant taking a presumably part-time university accredited course over three years to support free time work as a lay minister. Everyone who had participated considered this training useful. It helped participants 'understand what my design work was for'; 'help[ed] students and researchers engage in study and research into societal issues'; and 'Employment and regulatory integrity [are] ... critical in the pharmaceutical industry and are aligned for the most part with my personal values'. While the majority of respondents who had ethics education found it useful, it was not always sufficient in quality, quantity and range of coverage.

6.5 Further comments and suggestions

Participants noted the limited ethical training available and the importance of understanding ethical issues related to their work. They also referred to various potential conflicts, including between 'human centred values or technological commitment' and professional codes of ethics and commercial interests and 'scholarly/university values and neo-liberal values' and the shift in research towards commercialisation with the need for 'protection for scientists and engineers who put ethics before profit'. These comments parallel the literature on the binary divide in engineering with a focus on the technical and frequently a disconnect from the social and wider applications of their work (Faulkner 2000). However, they do not raise the gendered elements of this divide considered in the literature (Holth and Mellström 2011). Suggestions for improving ethical behaviour in professional practice by scientists and engineers included increasing opportunities for training and discussion, the production of professional ethics guides and standards and the development of regulatory protection for ethical behaviour. Suggestions also covered individuals publishing on ethical aspects of their professional work, joining communities of like-minded professionals and active 'engagement in the selection, design, and implementation of technology for socially useful purposes', paralleling the literature on socially useful applications of engineering, e.g. (Werner and PROJIMO 1998).

7 Discussion of results

Despite the low response rate, the sample is reasonably diverse and covers a number of different countries, a wide range of disciplines, several different career stages (with a bias towards greater experience), types and sizes of organisations (with particular representation of larger organisations and universities). The male gender bias is unfortunately typical of the population. While possibly not fully representative, the results give voice to the experiences, concerns and difficulties of a group of scientists and engineers and highlight some of the issues they face.

Ethical approval in most countries is only required for projects that involve people or animals. The strong support from participants for extending this to weapons, toxic materials and developments likely to have a negative effect on human health or society, or the environment indicates the timeliness of revisiting this issue. As indicated by the cautionary comments (though in principle I consider it difficult to take ethics 'too far') on the ability of ethics committees to take good decisions and the difficulties in identifying potential applications, the details would need to be considered carefully and regulations and guidelines

drawn up. Participants' comments indicate the desirability of evaluating the ethics of the outcomes and not just of the practices involved. This would convey an important message about ethics not just affecting projects involving people or animals and involving outcomes as well as processes. This would require value judgements, involving both personal beliefs and any available guidance. However, professionals frequently make value judgements with an element of subjectivity, for instance when evaluating research grants. Institutions with large military or other controversial grants are likely to be, at least initially, opposed due to the likely impacts on their funding. However, a change in research funding allocation and priorities could have a valuable effect on encouraging ethical socially useful research.

There were both differences and similarities in the ethical issues considered important in the professional and personal contexts and in these contexts and specific types of ethical decision-making. Overall, participants were concerned about honesty, integrity, transparency and relationships and caring for others in line with the literature e.g. (Loui 2005) and the ethics of care (Gilligan 1982). The overwhelming majority of participants had experienced ethical dilemmas, some of them fairly frequently. Some participants had taken a stand with possible personal risks in refusing jobs involving ethical compromises or where they felt unqualified.

Participants were not particularly positive about engaging in different types of military work. Surprisingly they showed greater refusal to participate in maintenance than research and development of various military related systems. This seems counter-intuitive and would require further investigation. Possible explanations are beliefs about the greater impact of maintaining existing systems than research and development, which may not be implemented, and greater interest in research and development than maintenance work. The greatest negativity was expressed about cluster bombs and landmines, followed by nuclear weapons, weapons considered inherently immoral (Fichtelberg 2006) and then data mining systems for surveillance. Concerns about intrusiveness and violations of privacy also emerged in the comments. Some participants considered military work justified on grounds of 'national defence' and others were totally opposed, but there were also participants who considered particular aspects of military work justified in some circumstances, for instance to make small arms safer or to understand the 'harmful' features of landmines and cluster bombs to make proposals to the United Nations about them. However, the harmful features of landmines and cluster bombs are well known and the only research requirements are for improved techniques for removing landmines. The Convention on Cluster Munitions entered into force in 2010 (Anon 2017), but there is not yet one on landmines. Making small arms 'safer' for users risks increasing rather than reducing their use.

Just over half the participants had participated in education or training on ethical issues as part of their university or vocational training and a third had participated in subsequent training, all voluntarily in the latter case. The overwhelming majority appreciated this education or training, including for helping them put their work into a wider perspective and supporting study and research on 'societal issues'. However, there were very varied approaches and amounts of time involved and the limited ethical training available was noted in additional comments. It is also worrying that nearly half the participants had not had ethical education or training as part of their initial qualification, though this may be due to many participants having studied before this became widespread. A highly prescriptive approach to the provision of ethics education and training is undesirable and would probably restrict creativity and a full coverage of the subject. However, there may be a need for stronger guidance. I would also suggest that there is value in a combined approach with both stand-alone ethics modules to cover basic principles and theory and the integration of ethics into other teaching. The latter can be very important in showing that ethics should be an integral part of all aspects of engineers' and scientists' work and not an extra.

While some respondents had a fairly traditional approach focussing on the need for national defence in line with just war theory (Norman 1995), others had considered relationships, equality issues and wider social and environmental issues, including the need to use human and financial resources for 'socially progressive purposes' in line with the ethics of care (Gilligan 1982) and moves beyond technical considerations (Nieusma and Tang 2012). Participants' comments showed that many of them had a vision of the type of society they would like their work to contribute to. A personal ethical commitment was important to several of the respondents with honesty and integrity the most frequently cited ethical factors that affected their professional lives and decision-making, in line with the literature (Loui 2005).

8 Conclusion

The paper draws on the literature and an empirical survey of scientists and engineers to investigate four questions related to ethical issues, values, professional ethics, military work and gender. The results extend the author's previous work in AI and Society on narrative ethics and science, technology and values (Hersh 2014, 2016). They also parallel continue discussion of some important themes in AI and Society, including narratives and the construction of technology and/or values, gender and human-centred design.

Engineers were originally military troops who built and operated military machinery (Tonso 1996) and there are still strong links between engineering, science and the military.

Technological developments have changed the nature of war and violent conflict, including through enabling killing at great distances, greatly increasing the number of casualties. They have reduced distinctions between combatants and non-combatants, so engineers and engineering technicians are possibly now the new frontline troops (Blue et al. 2013). The answers to the four questions presented in Sect. 1.3 will now be discussed.

In ethical terms, military work raises basic issues of avoiding or doing harm. Specific issues include the nature of the uses of weapons systems, including in conflict zones and countries with poor human rights records and in internal repression. Other issues relate to increasing militarisation and binary gendering of engineering and the impacts on those participating in conflict, e.g. a 'playstation' attitude to killing (UN 2010), as well as the extent and nature of conflict, the resulting loss of life and the distinction between combatants and non-combatants. Further issues relate to the resulting dependence of communities on military involvement, giving a need for diversification plans (STUC 2015; Unite 2016) and the diversion of resources from other problems, including peacebuilding approaches to resolving conflict (Hersh 2015a).

Ethical views and values were important to many participants with a stress on personal ethical commitment, with a focus on honesty and personal and scientific integrity (Loui 2005). Some participants expressed traditional views based on the need for national defence or relied on an ethical policy, without investigating whether it covered the relevant issues. Ethical factors which affected day-to-day professional decision-making included work ethics, professionalism, well being, avoiding harm, public safety, group development, mutual support, honesty and the freedom to exercise judgement. However, further work is required on how ethical views and values translate into professional practice.

Both the literature and the survey indicate that there is some awareness of wider issues and that in the case of survey participants this influenced their practice. Engineering education is increasingly integrating social and technical concerns and paying attention to social justice (Nieusma 2013). Wider issues raised by participants included impacts on people, animals and the environment. Some participants expressed concerns about relationships, providing support for colleagues in line with the ethics of care (Gilligan 1982) and the need for measures to encourage women and members of minority groups into science and engineering, in line with recognition of their exclusion (Seymour and Hewitt 1997). Job choices were influenced by wider issues including the employer's ethics and culture, avoiding harm, e.g. warfare, and particular issues related to data use, climate change, poverty and rights.

The role of gendered perspectives appears more clearly in the literature than survey responses. However, participants

were aware of (gender and race) equality issues and the need to open up engineering more widely and in some cases had taken measures to do this.

Engineering has been constructed as male and unsuitable for women (Pawley 2012; Powell et al. 2009). This gendering has, at least in part, been transmitted by a 'male' culture of 'tinkering' with machinery frequently given a female persona (McIlwee and Robinson 1992) and the transmission on of gendered knowledge from father to son (Holth and Mellström 2011). There has led to a binary divide with a focus on technical and professional competence as 'male' areas, but not wider social and environmental responsibilities and impacts (Blue et al. 2013) engineers. This 'masculinist' ideology has contributed to the exclusion of minority groups and individuals (Seymour and Hewitt 1997). Women were considered to disrupt engineering practices and norms simply by their presence, passion and competence for engineering (Bastalich et al. 2007), giving rise to a need for a change in culture. Difficulties with masculine culture and the likelihood of discomfort keeps many women out of science, engineering and technology careers (Glover et al. 1996) and leads others to change career after graduation (Skaggs 2013).

The paper enriches human-centred perspectives on ethics and design in a number of different ways. In particular, it discusses the impacts of gendered and binary perspectives, the exclusion of women and minority groups and the artificial and ethically problematical division between technical competence and wider social and environmental consequences. It considers the need for design to be carried out by those who are 'othered' and meet human needs rather than solely make a profit, as well as the importance of a focus on creation rather than destruction. The latter is particularly important when considering ethical applications of AI and related technologies. It further discusses survey results, which include the perspectives on human-centred ethics, amongst other issues, of a number of different engineers. The recommendations in the following sub-section help to bridge the gap between theory and practice. This includes through recommendations for carrying out engineering, including education, training and ethical approval, in ways that make human- and planet-centred ethics much more central. Further recommendations cover ways of making engineering culture more inclusive through gender, race and disability analysis, as well as encouragement for both individual and engineering community ethical commitments.

8.1 Recommendations

Consideration of the various issues raised in the paper has led to the following recommendations:

Education and training and ethical approval:

1. A much larger component of ethics in engineering and science education. This should include both stand-alone modules and integration into all teaching. It should cover the ethical implications of particular types of work and their likely outcomes, as well as the ethics of how engineers and scientists perform their roles.
2. Education and training in working with and involving end-users, including those from minority communities, in projects, particularly those related to technology design and development.
3. Production of additional case studies and other resources which cover wider ethical issues and not just professional practice, and development of a repository with links to these and existing resources.
4. A re-examination of the traditional restriction of ethical approval to research involving people or animals and its extension to research involving weapons or with military applications, potential harm to human health or society, or the environment and the development of toxic materials.

Organisational support:

5. Encouragement for engineers and scientists to join trade unions and to raise technology policy issues in them.
6. Setting up of forums where engineers and scientists can discuss ethical issues and obtain support from colleagues.
7. The professional institutions to provide a much greater lead on ethical issues and more support in the case of ethical dilemmas and whistleblowing.

Individual commitment and wider perspectives:

8. Application of gender, race, disability and other minority group analysis to engineering culture to make it more inclusive and decisions on technology development to make it more relevant.
9. Encouragement of engineers and scientists to consider their vision of the future and try to align their work with this vision and their beliefs about the type of society they would like to live in.
10. Encouragement of the use of a number of approaches, including narrative ethics and the ethic of care, to understand different perspectives, including those of minority groups and perceived 'enemies'.
11. Encouragement for engineers and scientists to make personal ethical commitments, discuss them with colleagues and in engineering and science organisations and seek support from colleagues and organisations to maintain them.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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