B 4 TAKING MORE ADVANTAGE OF THE POTENTIAL OF WOMEN IN THE RESEARCH AND INNOVATION SYSTEM

In the coming decades, demographic change is going to systematically and sustainably alter the size and composition of Germany's labour force. A shortage of skilled workers, particularly in the STEM professions (science, technology, engineering and mathematics) is increasingly creating a bottleneck for the innovative power and competitiveness of domestic companies and of Germany as a business and investment location.[338] It is therefore becoming more and more important to utilise skill and innovation potentials that have been previously underused – especially the potential of women, and especially in the STEM subjects.[339] Against this background, Germany's educational expansion of recent decades is a great success: today, more women than men are obtaining an academic degree. Yet, too much of women's potential is still underutilised for innovation. The following three factors are most important here: first, female students systematically choose other study fields than male students and are underrepresented in engineering courses – a field of study that is highly relevant in terms of its innovation potential. Second, the success of women in the education system does not result in similar subsequent success in the labour market. Instead, Germany loses the potential of the ever-growing number of highly qualified women in the transition to the labour market and in the career progression. Third, women are still significantly underrepresented in higher-ranking positions; in fact: the higher the career level, the more pronounced the shortage of women – despite the fact that today, female pupils and students in the German education system outperform their male counterparts when measured by grades, study duration and graduation rates.[340] The success of women in the education system in Germany does not continue in the labour market, despite their high education level – a phenomenon that does not apply to other European or non-European countries. Thus, it is hardly surprising that the proportion of female scientists employed in R&D is much lower in Germany compared to other European countries.[341] Germany does not tap the potential of cost-intensive, valuable investments in human capital, although these potentials are urgently required – especially in view of the current demographic development, global challenges and the internationalisation of innovation competition.

The status quo

Against this background, the Expert Commission has further analysed the participation of women in education and training and the participation of women in STEM subjects in particular. Here it could be observed that the number of women with a higher education entrance qualification has increased significantly over the last three decades. Between 1980 and 2010, this number more than doubled, and the proportion of women eligible for tertiary education was significantly higher than that of men. While in 1980 only 45 percent of all higher education entrance qualifications were held by women, the percentage rate steadily increased in the following years. Since 1995, the proportion of eligible females has exceeded that of males, with a proportion of 53 percent in 2010.

Irrespective of the educational expansion described, female students in Germany continue to systematically choose different subjects than male students and are underrepresented in engineering courses – a field of study that is particularly relevant to innovation. Female students still focus on a limited number of subjects, especially those from cultural and social sciences, and there has been little or no progress with regard to most of the STEM subjects and particularly to those STEM subjects with high innovation potential. An international comparison shows that Germany's proportion of female graduates is well below the EU 27 average – especially in the field of engineering sciences (22 percent as opposed to 28 percent), and far from the EU's leading group (Iceland and Greece with 40 percent). With an average of 30 percent, Eastern European countries have a very high proportion of female engineering graduates. Other countries such as Spain (34 percent), Italy (33 percent) and Sweden (30 percent) also seem to succeed – much more than Germany – in convincing young women to enroll in engineering courses. The situation is even more alarming due to the fact that, over the last few years, Germany's increase in female first-year students in engineering has been more moderate than that of its neighboring countries.[342]

At school level

So what are the reasons for this distortion in the choice of fields of study at Germany's higher education institutions in an international comparison? In fact, explanations can be found at all levels of Germany's education and employment systems.

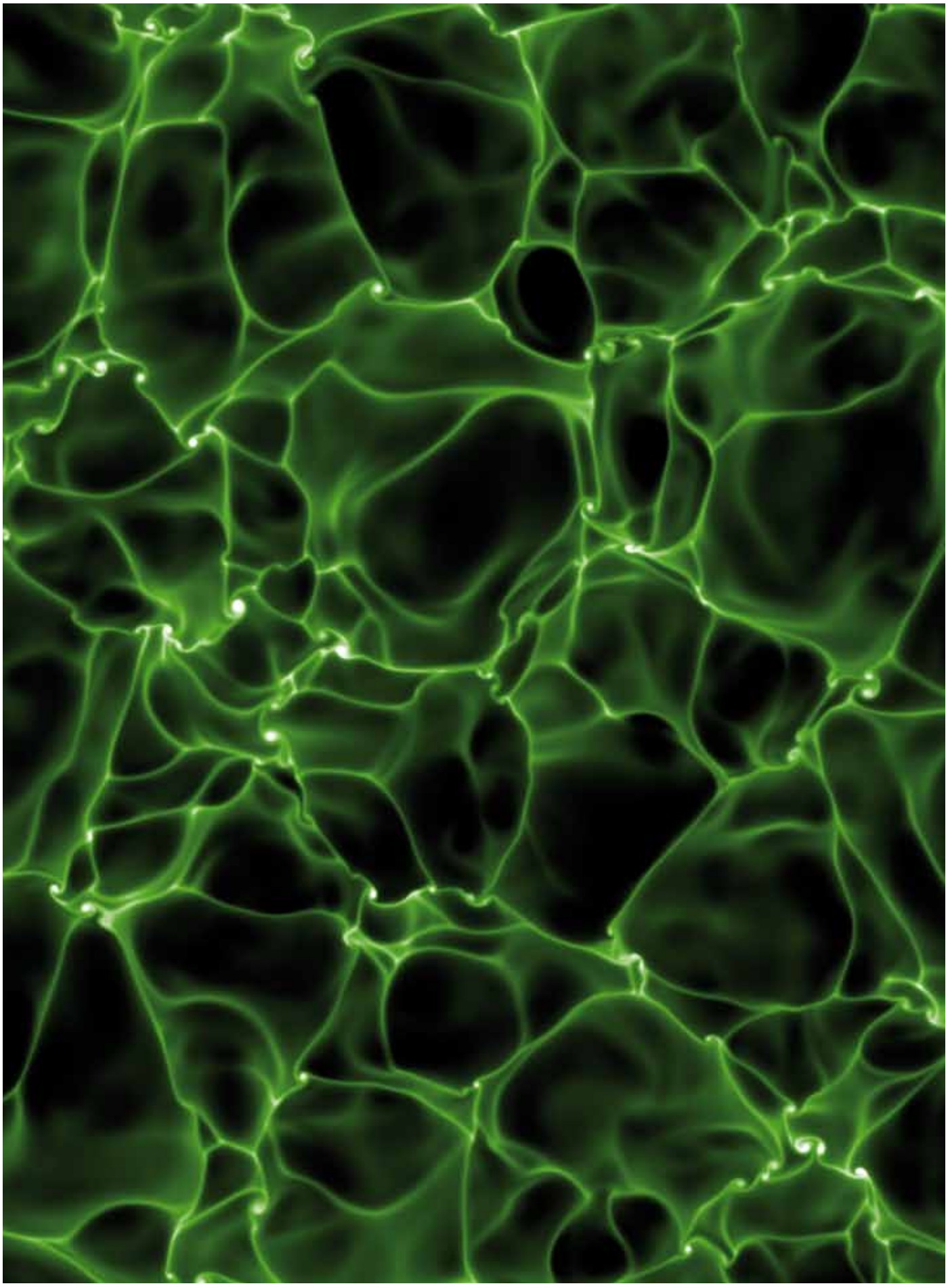
Already during primary and secondary schooling, one can detect differing interests and life concepts of girls and boys. Especially in Germany, the subjective perception of girls that they do not have a comparative advantage in technical skills is already being established at this early stage. Girls tend to see their strengths in the fields of (foreign) languages, communication, literature and music/arts, while boys tend to see their strengths in the domains of science and engineering.[343] While other countries also display a considerable gender gap in terms of pupils' self-perceived mathematical abilities, Germany is among the countries with the largest gaps; schools in Norway, Sweden and Russia seem to be more successful in counteracting this trend. In terms of self-perceived skills in natural sciences, the gender gap is substantially lower in other countries. Germany is one of the few countries where a statistically significant difference also prevails in the field of natural sciences.[344]

This leads to gender-specific differences in the prioritisation of subjects in secondary schools. The different scope of knowledge acquired in school is paving the way for gender-specific differences in deciding for or against a STEM field of study. The gender-specific prioritisation of subject groups at secondary schools leads to the fact that female students are less prepared for STEM degree courses, which further leads to the fact that female students less frequently enroll in a STEM course than male students.[345]

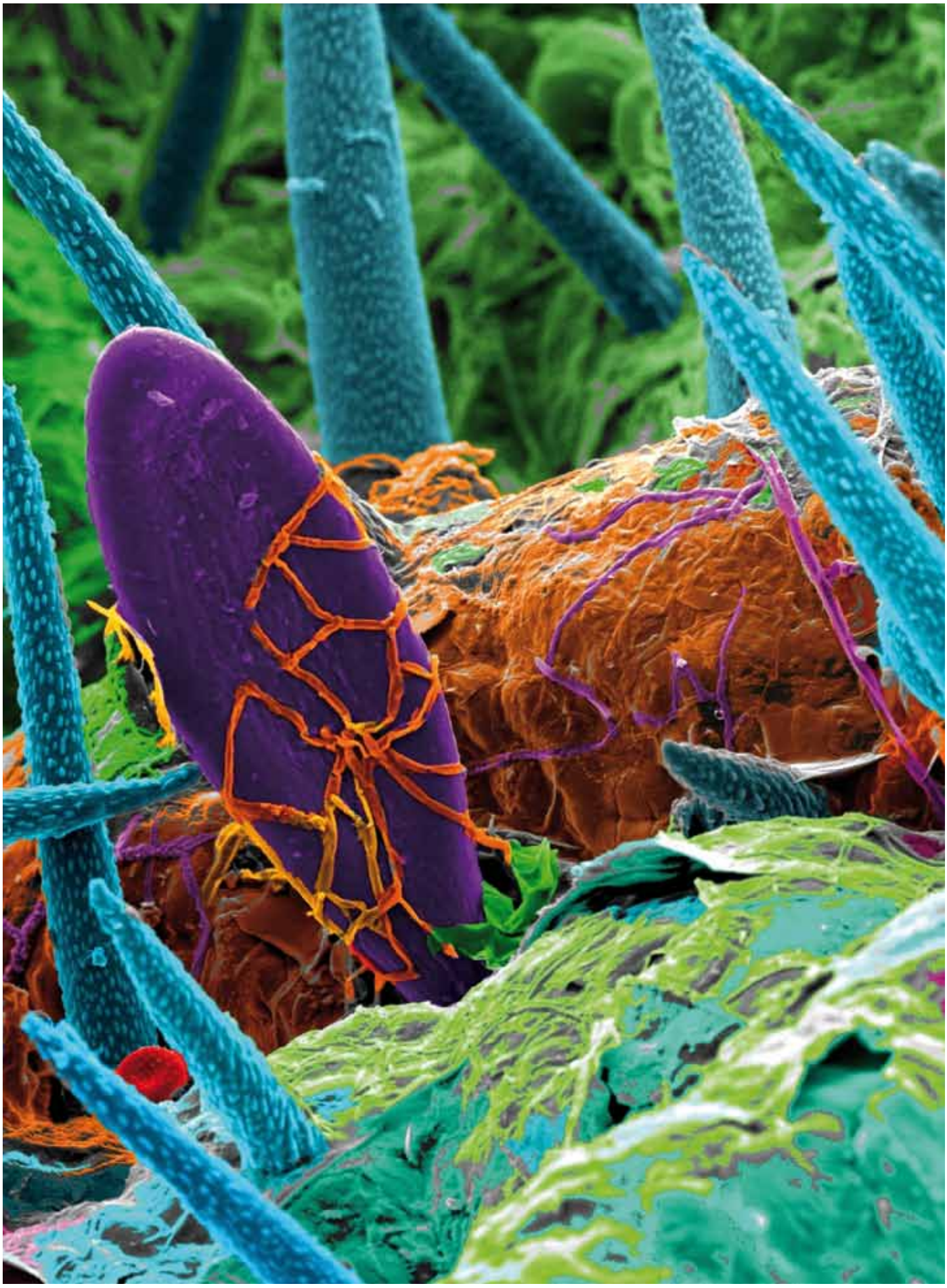
Yet, when it comes to introducing children to technical topics, it is not only the school, but also the parental home that plays an important role. Results from the 2006 PISA study on fifteen-year-olds indicate that in Germany both female and male pupils with parents working in a STEM profession have more advanced natural scientific competences than children from other backgrounds. Thus, it could be shown that children's natural scientific literacy is positively affected by natural scientific activities at home, parental career expectations and a personal appreciation of natural sciences.[346] Furthermore, children whose parents work in natural sciences or engineering professions have a higher probability of enrolling in a similar study course themselves than children without such a family background.[347] Parents, particularly those in science and engineering professions, should therefore take on the task of motivating their children, and especially their daughters, for STEM topics and stirring their interest in these topics.[348]

It is also quite striking that women's long-term career and life planning is more heavily influenced by intrinsic motives, while men are more likely to focus on career opportunities.[349] While women's decisions for STEM degree courses seldom stem from intrinsic motives, particularly in light of their detachment towards technical and mathematical subjects, as described above, men tend to perceive STEM degree courses as a particularly attractive career opportunity. Overall, it is hardly surprising that already at the age of 15 only 4 percent of girls in Germany can imagine themselves enrolling in an engineering or computer sciences degree course.[350]

However, the results for this age group are still largely similar in many other countries besides Germany. Yet, when examining the fields of study that are actually chosen at the later stage, other countries seem to be more successful than Germany in counteracting this phenomenon. In 2006, in none of the OECD countries the percentage of girls aged 15 who were planning to take up an engineering degree course amounted to more than 10 percent, while the OECD average for boys was 18 percent. However, differences in other OECD countries often turn out to be smaller when looking at the actual number of graduates from engineering degree courses. In some countries the proportion of female graduates from engineering degree courses amounts to as much as 40 percent[351], i.e. in the course of their educational career women nearly catch up with men. In Germany, however, the proportion of female engineering graduates amounts to only 22 percent – less than a quarter.



Turbulent currents during exchange processes occurring on the surface of water.



Coloured scanning electron microscope picture of an orange peel.

At university level

Although in Germany the proportion of women pursuing a STEM degree course is higher than the results of the survey among secondary school students would suggest, the proportion is still significantly lower than in other fields of study.[352] While more than 50 percent of newly enrolled male students pursue a STEM degree course, the proportion of female students in STEM subjects has been stagnating at about 23.5 percent for years. The proportion was particularly low in 2011 due to the suspension of mandatory military services, which lead to the enrollment of large numbers of male first-year students.[353] The most striking gap can be observed in the engineering sciences (with 20.6 percent of women enrolled in 2011), and in particular in electrical engineering (10.3 percent) as well as in mechanical, process and traffic engineering (17.2 percent). The gender gap is least pronounced in mathematics and natural sciences, where the proportion of women averages 36.0 percent. Female students are well represented in the fields of chemistry (42.3 percent), mathematics (50.5 percent) and biology (60.8 percent). The high proportion of women in mathematics and natural sciences is also attributable to the fact that female students often pursue a professional teaching degree with mathematics and biology being the chosen subjects of their curriculum.[354] The pronounced differences in female and male participation in individual STEM subjects suggest that the choice of a subject is not necessarily driven by a female aversion to skills and subjects perceived as masculine. As will be demonstrated below, there seem to be additional factors that emerge during study, and, especially, professional life. In fact, women seem to be generally very open towards fields of study other than cultural and social sciences, and yet in Germany this openness is currently not being utilised for the benefit of engineering or informatics. When comparing the different engineering courses, the low proportion of women is particularly striking in areas that display a particularly high number of patent applications, e.g. electrical and mechanical engineering – a fact that should also be given due attention.[355]

On a more positive note, it can be observed that women who have opted for an engineering degree do drop out of university less frequently than their male counterparts,[356] i.e. those few women who enroll in engineering degree courses are at least more likely to complete their studies successfully.

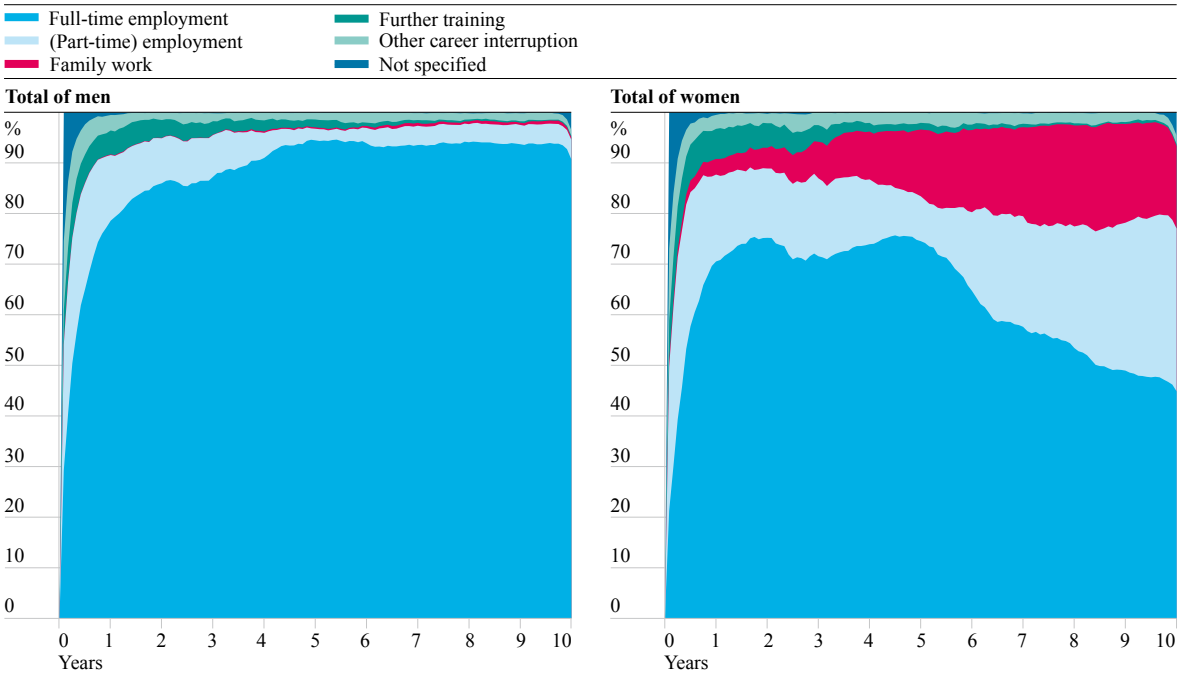
Labour force participation

The perceived benefits and development opportunities of a STEM degree play a key role when women decide for or against a STEM degree course. Surveys among individuals with a higher education entrance qualification show that women assess their expected labour market outcomes from graduating from a STEM subject lower than their male counterparts.[357] Thus, for women the perceived cost benefit trade-off of participating in a STEM course is unfavourable[358], i.e. women rarely decide in favour of STEM subjects. Also the labour force participation patterns of female engineers indicate that working conditions in engineering professions are not very attractive for female employees. As a result, Germany's labour market loses a large proportion of highly qualified female graduates; particularly those with an engineering degree.

Depending on the chosen field of study, considerable differences can be observed between the fields with regard to labour market entry and career paths. The family phase is especially characterised by a significant distortion in the participation of female graduates, and of female engineering graduates in particular. Figure 11 illustrates the labour force participation of an exemplary cohort of graduates from 1997 in the first ten years following their graduation.

The first of the surveyed years shows that – for both men and women – the transition from university to labour market does not tend to be seamless as many of the graduates enter the labour market only after an initial gap. For both full-time and part-time employment, this transitional process is usually completed within the course of a year. Already at this early stage, it can be observed that a significantly greater proportion of female graduates initially takes up part-time positions and also remains in such positions. Furthermore, there is an obvious trend among women to leave the labour market soon after their entry in order to pursue full-time family work.[359] This leads to the fact that ten years later only half of the female graduates are employed on a full-time basis, while the other half is at the most working part-time – often with a low number

FIG 11 **Employment in the first ten years following graduation in 1997, according to gender** (in percent)[360]



Source: Leszczensky et al. (2013).

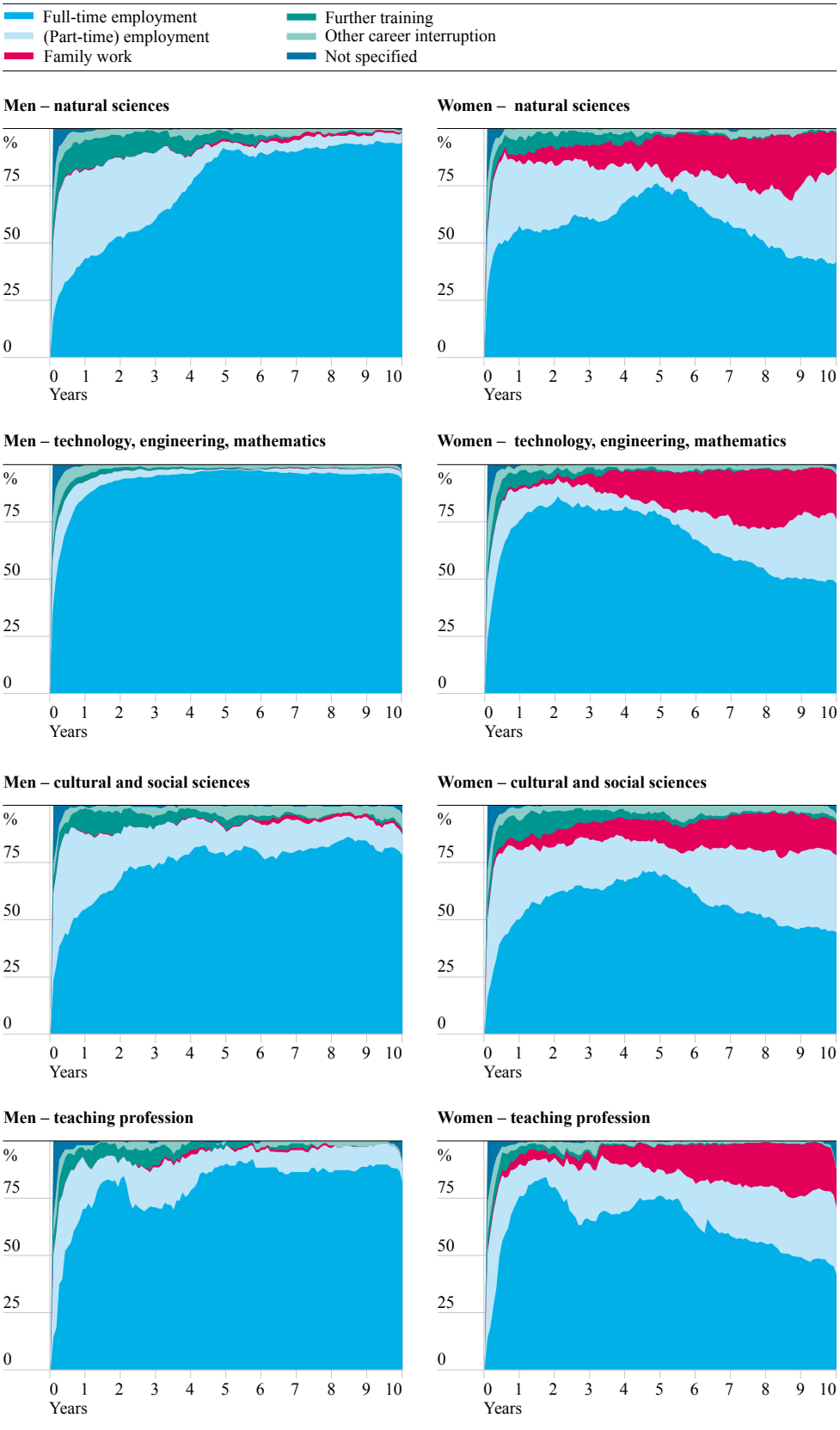
of hours – or refraining from the labour market altogether.[361] Measured in full-time equivalents and across all subjects, about one third of the labour force potential of highly skilled women is lost, compared to only about 5 percent of the male labour force potential. This is indeed an alarming finding, since empirical studies have repeatedly shown that such initial employment interruptions lead to lasting and often lifelong disadvantages in terms of labour force participation, unemployment risks and income levels.[362] When exclusively looking at employment rates among female university graduates in a European comparison, figures suggest that Germany is relatively well positioned with a rate of 84 percent in 2011 – nearly the same rate as that of the northern European countries, and even higher than that of France (78 percent) and Britain (79 percent).[363] However, a closer look reveals that among employed women with a higher education degree, the part-time rate is significantly higher than the EU average: in Germany almost 36 percent of women with a university degree are working part-time compared to the EU average of 25 percent.[364] Thus, measuring in full-time equivalents and taking into account long-term career prospects, Germany does not perform well in a European comparison. Moreover, the greater participation of women in other countries is not necessarily associated with a lower birth rate, as shown by France, Great Britain and the Scandinavian countries. With an average of 1.9 to 2.0 children per woman, these countries have a substantially higher birth rate than Germany (with an average of 1.4 children), and yet labour force participation levels of females are fairly similar.[365]

A closer look at female labour force participation in Germany according to fields of study indicates that there are significant field-specific differences (cf. Figure 12). Immediately after graduation, participation of women who had decided to take a degree in technology, engineering or mathematics (TEM) differs only little from that of male graduates. However, with the beginning of the family phase, female labour market participation literally collapses.

After ten years, the labour force participation of women in TEM professions is about as low as it is in other subjects (although the latter started with much lower labour force participation levels from the beginning). These figures clearly illustrate the specific problems of the employment situation of women in TEM professions. Although women who

Employment in the first ten years following graduation in 1997, according to fields of study and gender (in percent)[366]

FIG 12



Source: Leszczensky et al. (2013).

opt for TEM subjects prove with this choice that they have a high interest in labour force participation and indeed enter into employment just like men, they do not continue employment throughout the family phase. It can thus be assumed that working conditions in the TEM professions in Germany are particularly difficult to combine with family life, and that altering these conditions is a crucial starting point to improve the utilisation of the labour potential of women who have already completed a valuable TEM degree course.

When examining labour force participation in natural sciences professions, both women and men display certain structural patterns that differ significantly from other labour market segments. In the first six years of their working life, men display a strikingly high part-time rate (which is probably explained by part-time jobs during a PhD phase). This is usually followed by a typically male employment pattern, with more than 80 percent of men employed on a full-time basis. In terms of female labour market participation, it can be observed that an unusually high proportion of women initially participates: after one year, more than 90 percent are employed on a full-time or part-time basis. This high level of participation lasts for a relatively long period of time; the first five years are more frequently associated with full-time employment than would be the case in other professions, where the family phase would have already begun. However, the proportion of female full-time employees decreases significantly after five to six years and is only partially substituted by part-time employment.

A similar trend, albeit less pronounced, can be observed in the cultural and social sciences sector, an area that is particularly characterised by generally low participation rates for both women and men. When compared with other subject groups, male employment in cultural and social sciences is characterised by the lowest full-time rate, the highest part-time rate, and the highest share of other employment interruptions. Although in this domain female employment is characterised by a lower proportion of full-time employment and a relatively high and steady proportion of part-time employment, women only seldom withdraw completely from the labour market for the reason of family work. This suggests that the percentage of highly qualified women whose potential is completely lost is the lowest in the cultural and social sciences sector due to the part-time options available in this field. It can be assumed that this is attributable to the fact that many of these women are employed in the public services sector (especially schools and public authorities); institutions that provide clear-cut regulations for part-time employment.[367]

To sum up, it can be stated that women primarily choose fields of study (cultural and social sciences) that correspond with their educational interests and promise the best opportunities for combining working and family life. In this domain, large proportions of women contribute their skills to the labour force – even if only through part-time employment.

Corporate childcare projects of SMEs BOX 19

While large companies usually have enough staff to maintain in-house childcare facilities, SMEs are often lacking the critical size for operating their own daycare facilities. Yet, also in the realms of SMEs, successful models have been implemented to facilitate the reconciliation of working and family life through collaborative projects. Successful models comprise e.g. exclusive contracts with child minders,[368] the provision of places in existing facilities, and the establishment of facilities in cooperation with other SMEs. Examples of such facilities include the projects *Adventure Kids* and *Till Eulenspiegel*. The *Adventure Kids* project in Gütersloh[369] is a collaboration of seven SMEs that have established a joint group for their employees' children at the *Adventure Kids* daycare centre. The central location, the opening hours (12 hours a day from 7a.m. to 7p.m.) and the flexible care hours help the companies' employees to combine work and family. The corporate crèche *Till Eulenspiegel* in Braunschweig[370] was founded by two local companies. Again, opening hours are designed in a way to assist parents in balancing family and working life in the best possible way. Thus the crèche opens at 7a.m. to suit the employees' starting time. The crèche is situated in the immediate neighbourhood of the company, making it easier for employees to organise their daily routine.

Both projects were supported by the European Social Fund through the "Company-sponsored childcare" programme which expired in December 2012.

At the same time, in Germany, only a small proportion of women choose subjects that appear to be less suited for combining work and family (especially mathematics, engineering and technology, as opposed to natural sciences).

Against this background, corporate as well as family and education policy measures to combine work and family could positively affect women's study choices in favour of technology, engineering, and mathematics – e.g. via part-time options, flexible work schedules, corporate or community-based childcare facilities and day schools. This line of argument is supported by findings from neighbouring European countries. In the Scandinavian countries, which occupy a leading position with regard to family-friendly working conditions, women and men are provided with the most favourable opportunities for combining work and family. Denmark, Sweden and Norway are among the countries with the highest public expenditure on childcare and early childhood education.[371] Especially in Sweden, men also participate in childcare to a much higher extent. In fact, more than 80 percent of Swedish men make use of the parental leave option, taking more than 20 percent of paid parental leave days. Accordingly, the labour force participation of women having children under the age of one is comparatively high with more than 67 percent and steadily increases as the children grow older.[372] Within the OECD countries, Finland, Denmark and Sweden have the highest rate of companies offering flexible working time models, such as flexitime. Scandinavian companies take a leading role when it comes to models for adjusting working hours, i.e. reducing or increasing the weekly number of working hours.[373] As expected, the family-friendly design of work places in the Scandinavian countries corresponds with an above-average employment rate among women – including those with children.[374] In Sweden and Finland, the employment rate of women with three or more children is also high.[375] Whenever a solid childcare infrastructure and family-friendly working time models are in place, it seems that more women are willing to enroll in degree courses in the fields of informatics, engineering, manufacturing or civil engineering and to work in the respective professions at later stages. Although there are several successful projects in Germany that aim to facilitate the reconciliation of work and family (cf. Box 19), these and other measures have to be implemented to a much greater extent. The Federal Ministry of Family Affairs, Senior Citizens, Women and Youth (BMFSFJ) financially supports participating companies in establishing corporate daycare facilities via a corporate childcare support programme.[376] However, it is up to the companies to develop and implement intelligent and feasible solutions that suit their company-specific needs.

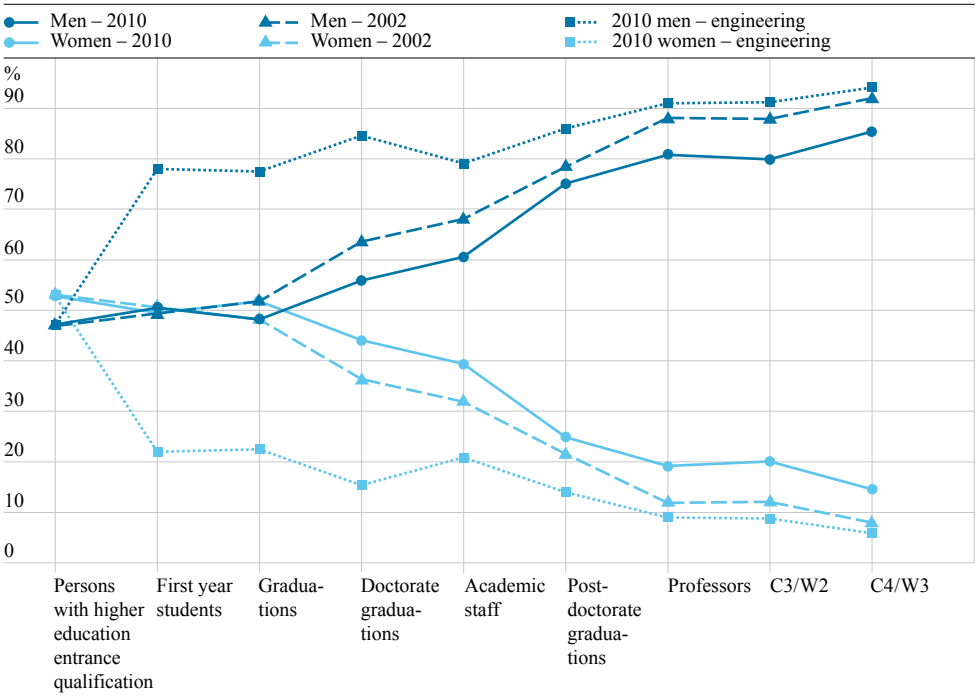
Career patterns and the "leaky pipeline"

The career patterns of men and women in Germany display further systematic differences in the first years following their entry into the labour market. Thus, the proportion of women decreases further at every ascending step of the educational and employment system – a phenomenon that is often referred to as the "leaky pipeline".

This phenomenon is particularly evident in the field of science, which is highly relevant in terms of its innovative potential (cf. Figure 13). In the context of Germany's educational expansion, the proportion of female secondary school graduates and first-year students has increased steadily and today even exceeds the male proportion. And yet this pipeline of talent leaks and becomes smaller with each additional level of education. This phenomenon is particularly evident in scientists' transition to the labour market and their progression within the labour market. Despite the above-average representation of women among individuals with a higher education entrance qualification (53 percent) and the gender balance among first-year students and graduates, women account for only 40 percent of PhD students and academic staff. The proportion even drops to 10 to 15 percent at the highest academic career level (C4/W3 professorships).

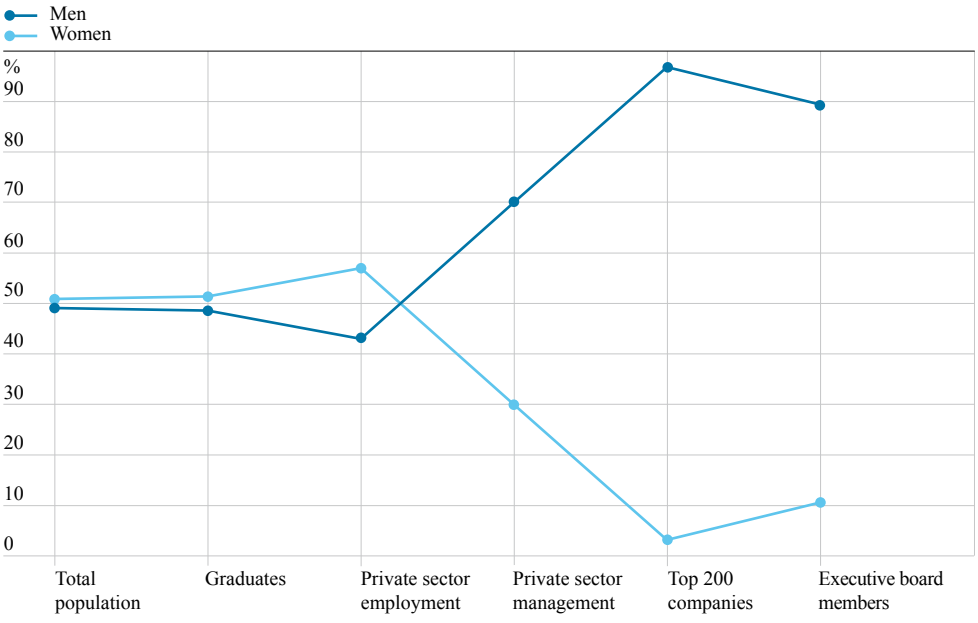
In the field of engineering (cf. Figure 13), the situation is also unsatisfactory, albeit for different reasons. With a proportion of newly enrolled female students of approximately 20 percent, the gender gap already occurs at the university entry level, but this gap does not widen much further, as it is the case in other fields of study. At each additional level of education, the proportion of women decreases slightly, and only 10 percent of women can be found to hold a C4/W3 professorship. When compared with other fields of study, the proportion of

FIG 13 **Share of women at different stages of a career in academia**



Source: Leszczensky et al. (2013).

FIG 14 **Share of men and women at different stages of a career in the private sector in 2010**



Source: own graph; data from Leszczensky et al. (2013), *Statistisches Jahrbuch 2012, DIW Führungskräfte - Monitor 2012.*

women is low but at least relatively stable throughout the entire academic career path. Thus, in engineering, the main bottleneck is the low number of women who can be convinced to enter an engineering degree course in the first place.

When interpreting the results shown in Figure 13, one certainly has to take into account that the educational and career paths leading to a professorship are relatively long. Consequently, a higher proportion of female students translates into a higher share of female professors only after more than a decade. And yet the long preparation period alone does not suffice to explain the low proportion of women among PhD students and academic staff, since these phases follow immediately after graduation. Hence, it is not very likely that the problem will just disappear over time. Although certain changes in trends can be observed when comparing results from 2002 and 2010, only little change is recorded at the advanced career levels when measured by the scope of inequality, i.e. the gender gap will not automatically close any time soon.

An international comparison reveals that a low proportion of women in senior scientist positions is not inevitable. When it comes to women's representation in management and decision-making positions in research (comparable to a professorship in Germany), Germany ranks with a share of 12 percent well below the EU 27 average of 19 percent and far behind the leading countries of Romania (32 percent) and Latvia (29 percent). Germany is also outperformed by Britain (17 percent), France (19 percent) and Finland (23 percent).[377]

In the United States, potential causes of the "leaky pipeline" phenomenon have been examined in the fields of biology and physics. Using an application process experiment, it could be shown that job applicants with female first names were assessed as being less competent by male and female professors than applicants with male first names – although the contents of the application documents were fully identical. The experiment further revealed that women are less likely to be hired, start off with a lower salary and receive less career support than male applicants. These results point to a subconscious discrimination against women based on culture-specific stereotypical opinions on the supposedly lower abilities of women in sciences; stereotypical opinions that seem to prevail among male and even female experts.[378]

However, the "leaky pipeline" problem is not limited to the science sector. Also in the private sector and the public sector, the proportion of women in management positions is significantly lower than their proportion of the total labour force (cf. Figure 14).

When comparing the proportion of women in supervisory boards internationally, Germany only occupies a medium position, ranking behind the Scandinavian countries, France and Great Britain.[379] Thus, in October 2012, the proportion of female DAX 30 non-executive board *(Aufsichtsrat)* members amounted to 15.6 percent, and the proportion of female executive board *(Vorstand)* members amounted to 4.2 percent. In Finland, for instance, the proportion of female non-executive board members was almost twice as high (27.9 percent), and for executives more than three times as high (14.9 percent). Other European countries outperforming Germany in this respect include Denmark with 16.1 percent and 11 percent, respectively, and the Netherlands with 18.8 percent and 8.8 percent, respectively.[380] In Norway, a country with a mandatory quota for women in supervisory boards,[381] 25 percent of corporate board members and 15 percent of executive committee members are female.[382] This shows that Germany is lagging behind dramatically, not only with regard to non-executive boards, but particularly with regard to executive boards.

Conclusion and recommendations

If Germany does not succeed in taking more advantage of the qualification and innovative potential of women, the shortage of highly qualified scientists in STEM professions will increasingly become a problem. International comparison shows that there are no inevitable obstacles responsible for the low proportion of women in STEM subjects and senior scientist positions. Other countries are more successful in convincing women to enroll in engineering degree courses, in retaining them in the labour market and in promoting them into high-level scientific or management positions. Germany is thus posed with the question of how political decision-makers and other stakeholders can contribute to improving the utilisation of the innovation potential of women.

– As already suggested in the Annual Report 2012, the Expert Commission recommends putting particular emphasis on the mathematical and technical education of girls at school level. Schools need to foster an interest in and enthusiasm for mathematical and technical issues among female pupils, thereby creating a solid technical basis and facilitating the decision to enroll in an engineering degree course at a later stage more frequently. In order to achieve these goals, the government has to provide adequate resources and trained teachers to ensure a high quality of teaching in STEM subjects.
– Since the choice of a field of study is largely based on perceived future working conditions, the Expert Commission further recommends promoting the expansion of childcare facilities instead of using available resources to pay childcare supplements. This would make it easier for women to participate in the labour force, and would create long-term incentives for an improved utilisation of the labour force potential of women – also in engineering professions.
– At the same time, the Expert Commission recommends the introduction of measures to support companies in providing family-friendly working conditions. The Scandinavian countries could serve as an example here, as they are particularly successful in distributing family work more evenly between men and women and in ensuring a high labour force participation of women – also in STEM professions and executive positions. In the Scandinavian countries, flexible working hours and a solid infrastructure for childcare and early childhood education are considered to be self-evident. As a result, the issue of combining work and family automatically plays a much smaller role among girls and young women when choosing a field of study, when entering the labour market, and when making career choices.
– Companies and research institutions should increase their efforts to solve the "leaky pipeline" problem, especially in domains that are largely male-dominated. There is clear evidence that even committee members and experts, who regard themselves as being purely factual and objective, make biased gender-specific decisions that disadvantage women. In their own interest, companies are therefore advised to establish internal processes to avoid unintended gender bias in their recruitment and selection processes, in their promotion decisions, and in filling management positions. A first step would be to systematically review all existing selection and promotion decisions by means of statistical and qualitative procedures to check them for implicit gender biases. Based on such a review process, company and process-specific countermeasures should be developed.
– Ultimately, the Expert Commission also considers the introduction of quotas for leading positions in academia and business as an appropriate means of accelerating the transition towards greater gender equality.