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Why don't young people want to become engineers? Rational reasons for disappointing decisions

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The quest for engineers during the past boom and predictions of future shortages have focused attention on the low enrolment figures in science and technology (S&T) subjects. Normally, it is assumed that young people shy away from 'tough majors' or make irrational choices, based on an absence of information. While not denying the fundamental necessity that a higher proportion of the population should have a background in S&T, this paper pursues a different approach. Only by identifying potentially valid reasons for the lack of interest in S&T will it be possible to change not just some 'misguided' perceptions among the younger generation, but to categorise the facts and make targeted recommendations for necessary changes. Therefore, this article will discuss the importance of image and status, the influence of society and peer groups, as well as financial rewards and career aspects. It will be shown that the universally observable trend away from S&T is not due to a dislike of technology on the part of the younger generation, but is caused by the fact that careers in this field do not seem attractive enough, especially in comparison with alternatives available in developed countries. Some recommendations to improve this situation are offered.

Keywords: career perspectives; engineering education; salaries; shortage of engineers; women in engineering

1. Introduction

An actual or impending shortage of engineers was the cause of much concern in the boom years before the financial crisis (e.g. Johnson 2006, Winckler 2006, Goossens 2007). The phenomenon is widespread (EU 2008), especially in industrialised countries (Sjøberg 2010) and is expected to become a hot topic again once the economy recovers (Tengelin 2009). The reason most often cited is the unwillingness of young people to pursue careers in engineering (Figure 1). Other factors include the high dropout rates among engineering students – rates typically ranging from 25 to 50% at German universities, for example – and the persistently low number of women enrolled in engineering.

The situation, which is unsatisfactory for society as well as for industry and for students, has been the subject of numerous, recently summarised studies, which, however, 'still largely focus on symptoms' (Prieto 2009). At the same time, it has triggered a plethora of initiatives aimed at

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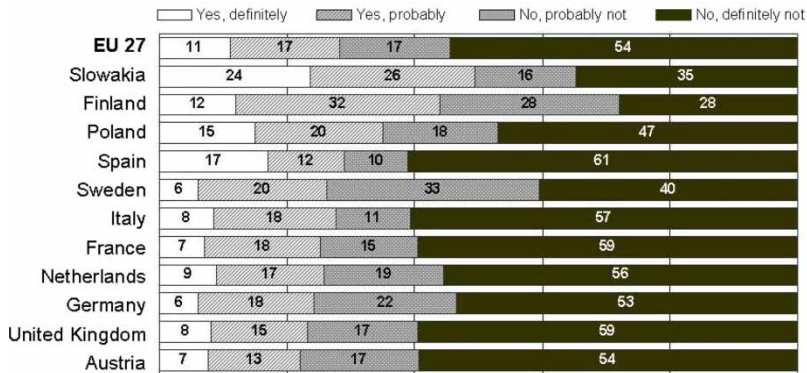


Figure 1. Willingness of young people to study engineering in selected European countries (EU 2008).

fostering interest in science and technology (S&T) – over 900 in Germany alone (MoMoTech 2009) and many more in other countries (Tengelin 2009). As the desired improvements have largely failed to materialise – that is, young people have persistently not reacted as hoped – there appear to be mainly two possible explanations:

1. Young people are too dumb to understand the advantages of an engineering career.
2. They are too clever to overlook its disadvantages.

Discussion to date has focused – if only implicitly – on the first assumption, which in turn has triggered even more well-intentioned efforts at persuasion. However, as the aim cannot be to talk unwilling or ungifted youngsters into engineering, this paper will explore the second alternative – even at the risk of debunking some common myths and presenting unpleasant truths. If change is really desired, it is on the ‘adult’ decision makers in society to dispense with wishful thinking and try to respect the reasons the target group may have for disregarding their unanimous advice. Only then will it be possible to identify the real obstacles and to categorise them according to ‘cannot be changed’, ‘can only be improved in a wider societal context’ or ‘has to be changed by . . . schools, universities, or companies, etc’. To this end, this article will analyse a host of studies, including the results of a recent large-scale survey undertaken in Germany (NaBaTech 2009) as well as anecdotal German evidence.

2. The changing role of engineers and technology

The second half of the nineteenth century was the age of engineers, with pioneering figures such as Edison and Siemens. In an environment still largely technology-free, the challenge then was to develop working innovations and not – as it is today – to prevail in an intensively competitive market, where a wide array of non-technical factors determine success. Engineering brought progress visible to all: railways; electric lighting and motors in factories; automobiles; steamships; radio communications; X-rays; telephone links; airplanes; and a host of other inventions.

As a result, engineers and natural scientists could be the heroes of popular, technology-oriented novels such as those of Jules Verne in France and Hans Dominik in Germany, which had a readership of millions. Despite the misuse to which technology was put in World War II, the faith in progress that inspired those novels remained widespread until the late 1960s. Since then, however, a reaction against S&T has set in, fuelled by the increasing opaqueness of modern technologies and the rise of the environmentalist movement. Visions were lost – that is, the belief

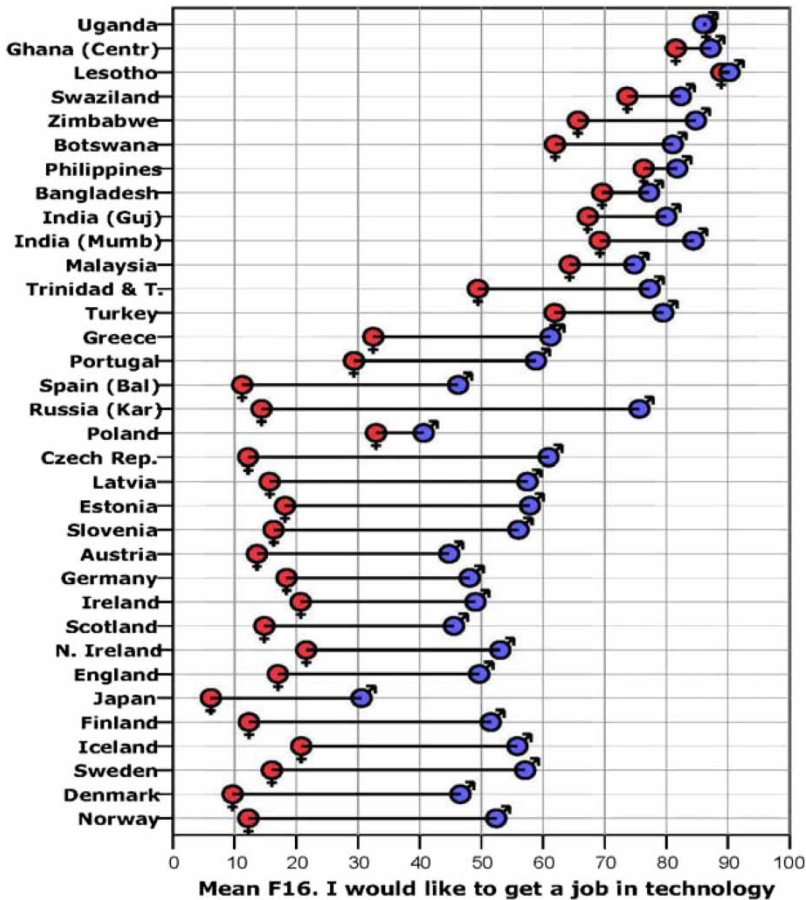


Figure 2. Willingness of young women (♀) and young men (♂) to become engineers in different countries (Sjøberg 2010). Countries with the highest Human Development Index are lowest on the vertical axis.

waned ‘that the future should be better than the past’ and ‘that everything can and should be improved’ (Winckler 2006). This has significantly impaired the reputation of engineers, as the clear link between new technologies and better living standards has become blurred – a connection still evident in today’s industrialising nations. Here, the percentage of young people wanting to pursue careers in engineering is much higher, as illustrated in Figure 2. This difference is especially pronounced for girls, a finding that will be discussed in section 7.

In the developed countries, omnipresent technology has become an element of everyday life – something merely consumed (‘switched on’) and taken for granted. This high-tech saturation is paralleled by the ‘invisibility of technology’ – that is, the reliance of performance on hidden features such as microelectronics and software. Most highly qualified work – be it text production, administration tasks, graphics design, factory simulation or the development of new turbines – now primarily involves the computer screen. As a rule, direct, hands-on technology experience is nearly impossible in the everyday environment; thus, eliminating a strong incentive for pursuing it.

Although the importance of S&T for the foundation of society as well as for everyday life has continued to grow, the gap between technology ‘nerds’ and technology users has widened. Consequently, starting in the 1980s, an increasing number of more or less technically trained users, who were able to convert the new opportunities created by microelectronics, software and later the Internet into successful business models, rose to stardom. The signal was not lost

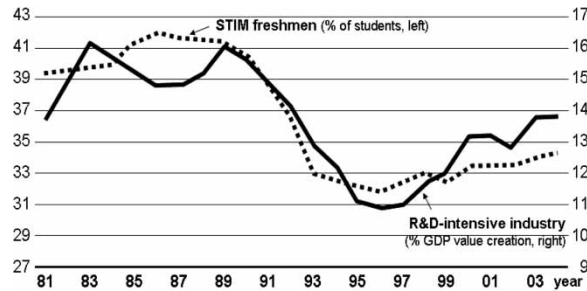


Figure 3. The enrolment in science, technology, information technology and mathematics (STIM) majors parallels the importance of the research and development-intensive industry in Germany (Meyer 2008). GDP = gross domestic product.

on the younger generation, whose interest in science, technology, information technology and mathematics developed (as Figure 3 shows for Germany) largely parallel to the importance of research-intensive industries.

However, the slight rebound of the share of German industry as a percentage of gross domestic product (GDP), noticeable since the mid-1990s (Meyer 2008), is a specific phenomenon not seen in most developed economies. For this reason, the relatively small percentage of young people in practically all Organisation for Economic Co-operation and Development (OECD) countries opting for engineering and science can be interpreted as a rational reaction to the trend toward a service economy in which the skills increasingly demanded are not taught in conventional engineering programmes.

3. Fascinating technology – but off-putting university programmes

The debate about the content of engineering courses is age-old and curricular reforms advocated by the business community have been as frequent as they are ineffectual (Becker 2006a, 2009). The hopes for a more practice-oriented and career-enabling undergraduate curriculum that had been raised by the Bologna-Process in Germany have been only partially realised. Traditional university representatives often express doubts about the acceptance of undergraduates in the labour market. However, their real concern – dictated understandably by their own interests – is that they might lose their best students to industry before they can contribute to university research. Professor Gerlach (2007) from TU Dresden described the danger:

Look at what goes on in the United States. Headhunters use money to entice the top students with bachelor's degrees of U.S. colleges into industry. Many students who should have gone on to graduate school, completed PhDs and gone into research don't because they've been lured away by the prospects of high salaries.

Professor Henning (2007), dean of the Faculty of Mechanical Engineering of the RWTH Aachen stated: 'We don't want students to leave the university with only a bachelor's degree. But I'm afraid that, when engineers are in short supply, industry will entice them away'. In line with these statements, 83% of German university professors did not consider the BA to be a stand-alone degree but 'rather an intermediate step on the way to an MA' (Minks 2007). The TU9, a pressure-group of nine traditional German technical universities (among them Aachen and Dresden), have publicly stated that only a master's degree is equivalent to the former German *Diplomingenieur* degree – in spite of the fact that about 60% of all German engineers are graduates of *Fachhochschulen* (Universities of Applied Sciences), where the standard degree is now the bachelor's instead of the '*Diplomingenieur* (FH)'. The position adopted by the TU9 has done

much to discredit the bachelor's degree in the eyes of students as well as potential employers. The negative effects of this position are twofold:

- The high threshold (minimum 5 years) for achieving this 'real' master's degree puts off most young people who are interested in S&T, but do not want to commit themselves for such a long time exclusively to engineering.
- As the bachelor's curriculum is not optimised to be a practical 'degree relevant for the labour market', but mainly the theoretical foundation for the master's, it fails to fulfil the expectations of students who have chosen engineering because they are attracted by technological applications (NaBaTech 2009).

As a consequence, the old, well-known problems of the traditional diploma that have produced high dropout rates in the early study phase are bound to continue.

For historical reasons, engineering students at German universities spend their first four semesters learning mostly theory. Practical applications are taught only later. As a result, the first years are more frustrating than enjoyable. Pedagogically considered, this approach violates all the basic principles of education, since it is questions of practical application that arouse an interest in theory and not the other way around.

(Pritschow 2004)

Added to this is the elite attitude of many professors who believe that the study of engineering is and must be something particularly difficult. This has led the rector of one leading German technical university to attribute the declining interest in the subject to young people's 'unwillingness to suffer' – but not, of course, to unattractive teaching! It only remains to explain why these 'engineering-averse' young people then go on to pursue degrees in other fields, such as economics, law and medicine, which hardly involve a walk in the park. . .

To be fair, it should be noted that the government does not support engineering teaching to the extent required. For example, between 1995 and 2005, 10.6% of such 'expensive' professorships were eliminated at German universities of applied sciences and even more, 13.3%, at German universities (IW 2008).

But high dropout rates – due also to financial difficulties and the temptations of the labour market (VDMA 2009) – are by no means the only negative consequences of an intense, theory-laden curriculum that leaves those students who cannot complete the minimum 10 semesters of work required for a master's degree in their own eyes without a sufficient qualification. The deterrent created by this high threshold is so serious that it has helped make engineering the preserve of specialists with narrow interests, while industry cries out for problem solvers with wide horizons (Becker 2006a). At the same time, it scares away young women, a topic dealt with in section 7. Studies show that precisely those young people who, because of their broader natural abilities, can pick and choose which career path they want to follow, tend to turn their backs on engineering (Minks 2005), especially as the profession has lost its reputation of providing secure jobs.

4. Reliability of predictions: retrain engineers as plumbers

'Like every market, the market for engineers is characterised by imbalances between supply and demand. Both empirical observations and theoretical considerations indicate that, in the normal case, this relationship consists of a systematic mismatch – that is, a fit that is inexact both in terms of numbers and in terms of qualifications. An overview of labour market cycles over the past 23 years shows us, as empirical university and job researchers,

- that projections and prognoses of the future demand for engineers have proven to be imprecise and mistaken and

- that, following their announcement, these forecasts have caused participants to ‘overreact’, which, in turn, has often led to a disparity between the supply of and the demand for engineers – a frequently noted divergence that intensifies from cycle to cycle.

(Winkler 1996)

This sobering assessment was made when – in the wake of an economic crisis and the collapse of engineering-based industries in the former East Germany – whole age-groups of German university graduates found themselves without employment. They had relied on rosy predictions of a promising future:

In the middle of the 1990s, the number of available graduates in the area of electrical engineering will no longer be sufficient to meet the needs of industry for young electrical engineers. Educational policymakers and industry associations based this conclusion on the estimated student numbers, on the one hand, and on the demand for electrical engineers expected in the mid 1990s, on the other.

(ZVEI 1987)

Much more dramatic was the explosion in the numbers of unemployed engineers over the age of 40 years, which, in the case of electrical engineers, for example, exceeded 300%. Of course the economic slump also impacted other professions and no one could have predicted the sudden reunification of Germany. (That such disruptive events must always be taken into account, however, is shown by the terrorist attacks of 2001 and the financial crisis of 2008.) But for security-oriented engineers and information technology (IT) specialists, who frequently came from upwardly mobile families (4Ing 2009, Hartmann 2009), this was a new and particularly bitter experience, which still lingers in the ‘collective memory’, as will be discussed in section 8. In the 1990s, young people got the message and, as Figure 4 shows, turned their backs on engineering studies in droves.

Their market-oriented reaction was in line with the statements of political leaders and industry associations. A ‘Forum for Innovation’ organised in 1997 came to the resigned conclusion that ‘no positive job developments in the conventional fields of engineering and the sciences are to be expected in the foreseeable future’. At the Forum, leading specialists discussed ‘how the transition from engineers and natural scientists to alternative fields can be supported’. In this connection, the ‘engineers-as-craftsman-model’ was touted as particularly promising (Staudt 1998).

But within only 2 years, the world had changed once more, reports on the lack of IT experts filled the media and university graduates were now in short supply (Figure 4).

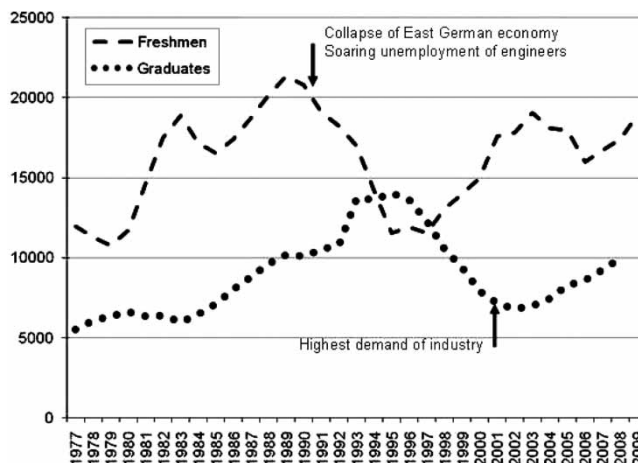


Figure 4. Development of freshmen and graduates in electrical engineering in Germany (ZVEI). Enrolment is strongly influenced by economic perspectives.

Mismatches between the number of qualified university graduates and the number of job openings will be impossible to avoid in the future since, as the example of Siemens shows (Becker 2006b), companies' hiring patterns are generally linked to market cycles. In this connection, claims that the EU may lack as many as 700,000 researchers are to be treated cautiously. Such claims arise from the politically motivated, but far from realised goal of increasing research and development expenditures in the future to 3% of total EU GDP from their current 1.9%.

As a general rule, however, university graduates with degrees in science- and technology-related subjects ought to have above-average job entry prospects, even in difficult times. The prerequisite, however, is that students are not fixated on a single specialist career path but regard their university education primarily as a training in the ability to think. This attitude is much more common in English-speaking countries, where the connection between college major and career path is looser (for example, Abbot 2003). The rigorous focus on specialist training in Germany's technically excellent engineering schools is both one of their strengths and one of their fundamental problems – especially if graduates want to move up in the corporate hierarchy.

5. Engineering – the fast career track to the top?

Complaints about the one-sidedness of engineering studies have a long tradition (Becker 2009). In this respect, the transfer of a large number of German S&T departments to remote and secluded 'science ghettos' in the 1960s (for example, Marburg, Tübingen, Munich-Garching) was detrimental to the goal of fostering the wider perspective required in a modern service economy.

In Germany today, the system for educating engineers is quite successful in promoting theoretical expertise but less so in meeting other job requirements, as surveys of young engineers regularly reveal. The information presented in Figure 5 is representative of many analyses. The picture is a bit less dramatic if the softer 'important/rather well taught' categories are also included, but the general impression remains (Becker 2009).

The ease with which engineering graduates have been able to find jobs in recent years seems to belie these findings or render the discrepancies irrelevant, but this topic will be discussed later. In fact, the good job offers for entry-level positions, especially in 2006–2008, are often cited as an argument for the profession's attractiveness and salaries for engineers can be 25% higher than for graduates in the humanities (IW 2008, Fabian 2009). As this situation has still not, however, triggered a stampede into engineering, the situation calls for closer examination.

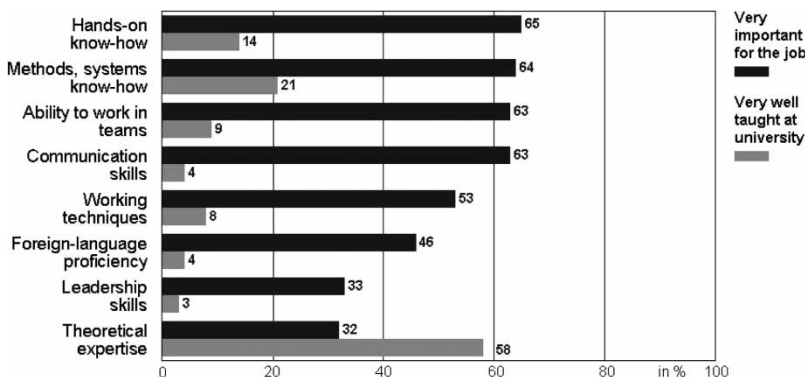


Figure 5. Disparity between knowledge taught at universities and know-how required in the workplace (VDE 2009).

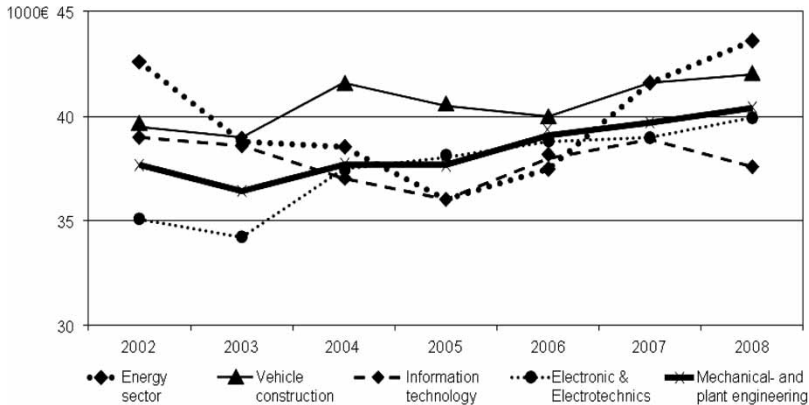


Figure 6. Development of entry-level salaries for different groups of engineers in Germany (VDI 2009). No 'shortage bonus' can be detected.

In a market economy, a shortage manifests itself by increasing 'prices', that is, salaries, an effect that could motivate young people to choose the profession. But can this really be observed in the labour market? Unfortunately, the available data do not support this conclusion.

In Germany, the development of entry-level salaries for engineers in the industries (shown in Figure 6), if adjusted for the cumulated inflation of 11.8%, indicates, undeniably, a drop in real-term buying-power in most sectors (VDI 2009). These findings are confirmed by a study analysing the general salary development of engineers between 1990 and 2008 (VDI 2010). Other professions may have suffered declines as well – but this paper is discussing a highly qualified group allegedly in urgent demand. It does not take much to see that in the eyes of the target group, which is also able to calculate, the much-debated shortage of engineers has failed to produce positive results.

A similar effect has been observed in other countries. In a much-discussed statement, Lars Pallesen, rector of the highly respected Danish Technical University in Copenhagen, called talks of an engineer shortage 'cant' (klynk) on the grounds that otherwise the salaries of Danish engineers would be higher (Pallesen 2007). In Switzerland, Elisabeth Baume-Schneider, Secretary of State for Education, Culture and Sport, stated in 2007: 'Fears about a shortage of engineers have been expressed for many years but, as far as I know, engineers' wages haven't been increasing at a rate that might confirm that alleged scarcity . . .' (Goossens 2007). In the USA, a study of the period from 1970 to 2000 produced the sobering result that: 'altogether the data . . . do not portray the kind of vigorous employment and earnings prospects that would be expected to draw increasing numbers of bright and informed young people into the science and engineering fields' (Butz 2004). Therefore, the EU warned that: 'scientists – especially young ones – need better salaries. . . New human resources for science and technology will not be attracted at the required level unless governments translate their political goals urgently into new research jobs and better career perspectives' (Gago 2004).

Of course, even in a market economy, there is no strict correlation between a shortage of applicants and salary increases (otherwise the exorbitant rise in managing board pay in the past would point to a serious lack of capable candidates . . .). Here, factors such as mindset, training and negotiating power play an important role. But such power depends to a large extent on the background of the top decision makers. Here, too, it does not look good for engineers, for whom seniority is seldom a bonus and who are not optimally prepared for a management career by their educational background.

The management skills mismatch shown in Figure 7 has to be taken seriously, since PhDs are an absolutely elite group, which even in a company such as Siemens account for only 3% of

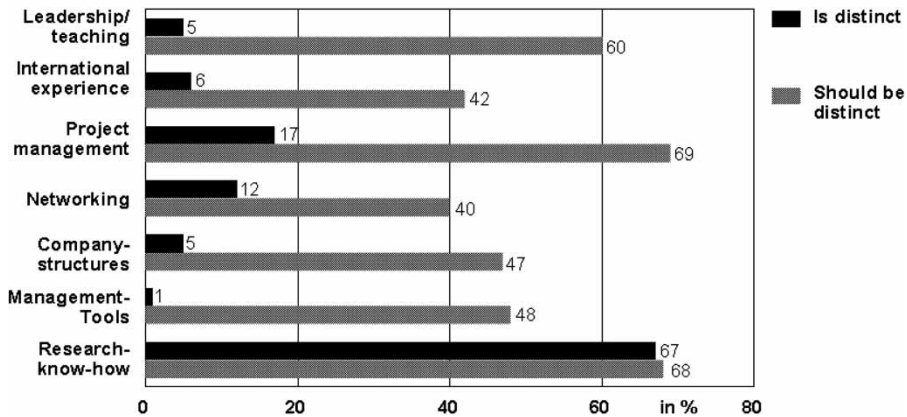


Figure 7. Comparison of skills expected by employers in the machine-tool industry and their evaluation of the actual performance of PhD graduates (VDMA 2007).

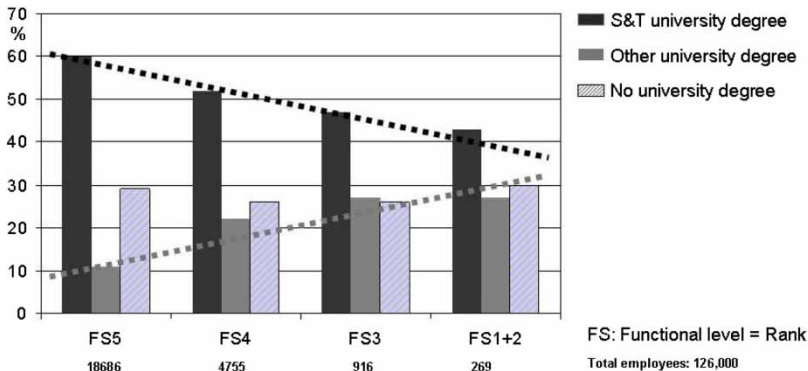


Figure 8. Decline in the percentage of managers with a technical background vs. rank (Siemens Germany, August 2008). S&T = science and technology.

the total workforce (Becker 2006b). If not offset, these deficiencies can turn into serious career obstacles. Comparable findings have been reported in other countries (e.g. Nair *et al.* 2009) and point to a general problem in engineering education. Studies indicate that engineers are willing to become managers (Schmauder 2004, Universum 2009). They are, however, more motivated by their distrust of the career opportunities available to them as technical specialists (Schmauder 2004) than by a drive to leave their world of solid, calculable facts and move into an area more determined by human interaction, economic necessities and personal vanity (Reisach 2010), for which their educational background did not prepare them well.

Consequently, even in a technologically oriented company such as Siemens, in which the environment is surely favourable, training as an engineer or scientist is far from being the best career track to a top position. This is clearly indicated by the relationship (shown in Figure 8) between the educational background of Siemens managers and their relative position in the company hierarchy.

This trend, which increases as one moves upwards, has become stronger over time. In 2010, only 25% of Siemens' managing board members were scientists and engineers; in 2001, this figure was 64%. In small and medium-sized enterprises, the situation is different, but the big companies are the showcase and offer the highest salaries (VDI 2009).

The 'best and brightest' young minds – who are always and everywhere in demand – are well able to calculate and judge which type of education will lead them to the top positions in companies, and in society.

6. Image and status in society

The changing attitude of society toward technology, mentioned in section 2, has had a negative impact on the image of engineers. In a survey conducted in 1971 by the German sociologist Eugen Kogon, 72% of some 25,000 responding engineers agreed grudgingly to the statement that ‘engineers are the camels on which businessmen and politicians ride’ (Kogon 1971). This situation has not significantly improved – in spite of the fact that technology is now omnipresent. Young users are fascinated by it, but this does not translate into a high respect for the profession that creates all these devices (NaBaTech 2009). As Figure 9 shows, there is a large gap between the positive self-perception of engineers and the external view, except with regard to good career prospects (VDE 2007). Values shown in parentheses give the results of the 2003 survey.

In general, and not only for young women, society fails to provide sufficient visible ‘role models’ of people who have succeeded as engineers rather than by switching from engineering to another profession. As a matter of fact, this is a media-dominated ‘jackpot society’, in which the apparent success of a few – albeit highly unlikely – ‘winners’ motivates considerably more young people to invest in such ‘lottery ticket careers’ than in less thrilling, but more secure alternatives. It is a safe bet that the normal engineer earns more than the average pop musician or actor, but there are actors or musicians who earn tens of millions of dollars per year. Even if money is not everything, high salaries and the fame and media attention that comes with them lend glamour to an entire profession. Engineers, on the other hand, do not figure in the mass media and are

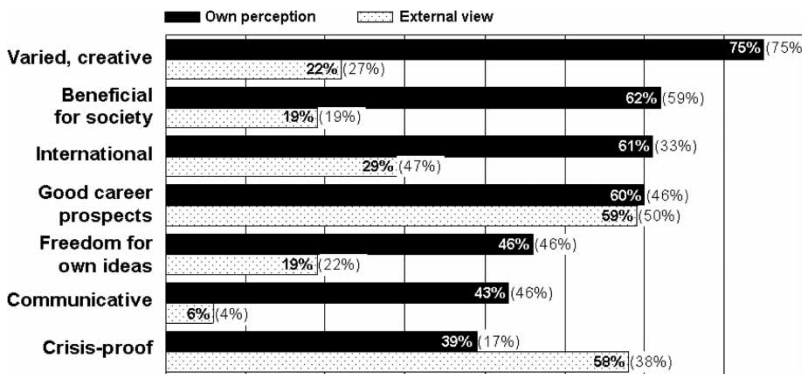


Figure 9. Discrepancy between the positive perception of young engineers and the more negative view of the outside world. (VDE 2007).

Table 1. Different yardsticks in society for rewarding intellectual creativity.

Texts and music	Technical inventions
To register: easy, cost-free (in Germany VG Wort, GEMA)	To get a patent: expensive, difficult (patent attorney, Patent Office)
To maintain rights: free of charge	To maintain rights: rising costs!
Fees collected up to 70 years after death of author	Maximum duration: ca. 20 years after patent granted, royalties only if used
GEMA: actively protecting authors' rights and collecting royalties	Patent Office: no action taken to support inventors
Questions to think about:	
<ul style="list-style-type: none"> • Who got famous and made the millions – the inventor of the CD or pop stars such as The Rolling Stones, Madonna, Lady Gaga? • Who could veto the modification of the Munich Olympic stadium 30 years after the games – the civil engineer who constructed it or the architect? 	

portrayed at best as harmless eccentrics, such as the comic figure Gyro Gearloose. Also, the often remote location of typical engineering jobs is considered unattractive (Alpay 2008).

Finally, society also applies different criteria in the area of ‘prominence’ and intellectual property rights – criteria that clearly discriminate against creativity in technological fields. Table 1 lists some of the factors that, curiously enough, are frequently overlooked in the public debate.

This disparity between the proclaimed goals and the reality of the social environment sends signals that young people understand perfectly well. Seen in this light, their reaction is a sad, but logical consequence, not an erroneous decision based on a lack of ‘good advice’.

7. Women – aliens in engineering

Engineering fields are traditionally dominated by men – but is this a law of nature? Women in Germany were first admitted to universities only about a century ago, but are now very well represented, accounting for more than 50% of total enrolment. They have gained strong positions, even in a number of scientific subjects, as shown in Figure 10, based on 2007 data.

However, as soon as the word ‘engineering’ appears, their share drops dramatically, an effect also known in other countries (e.g. Eisen 2009). But all attempts to explain by ‘hard facts’ why young women continue to avoid electrical engineering, for example, (in spite of all initiatives to attract them) have been quite unsuccessful.

The only conclusive observation is that women go where they feel at home (Eisen 2009, Gräßle 2009); that is, where they have overcome a critical threshold that is probably $> 30\%$. After all, the often-cited incompatibility of work and family applies just as much to careers in chemistry (not to speak of law, advertising or medicine, where irregular hours are the norm). In view of the fact that women now account for half of all students of mathematics (VDI), it is not the rigors of this discipline that can be the problem either (Gräßle 2009).

As Figure 2 shows, the unwillingness of young women to become engineers is even more pronounced in highly developed countries (Sjøberg 2010). The more ‘emancipated’ a society is and the greater the range of alternatives that a highly differentiated labour market offers young women, the less they will be inclined to opt for professions they do not wish to identify with. Since this is far too complex a matter to deal with within the limited space of this article, it merely remains to be said that particular sensitivity and support is necessary here – from a psychological

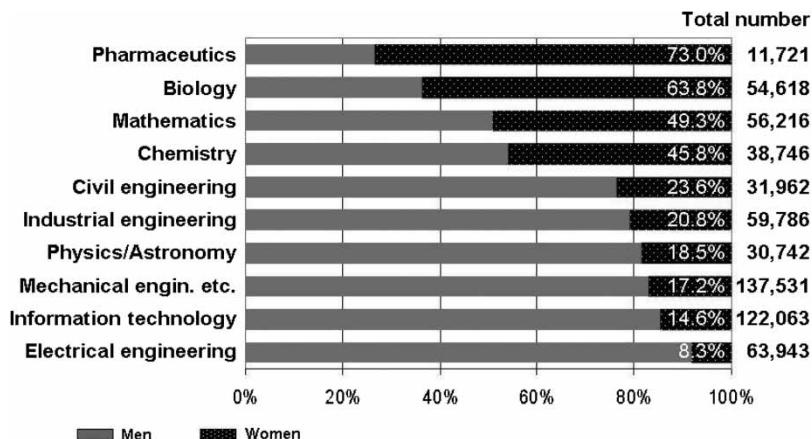


Figure 10. Percentage of women in different scientific majors at German universities. Right: Total students enrolled. (VDI).

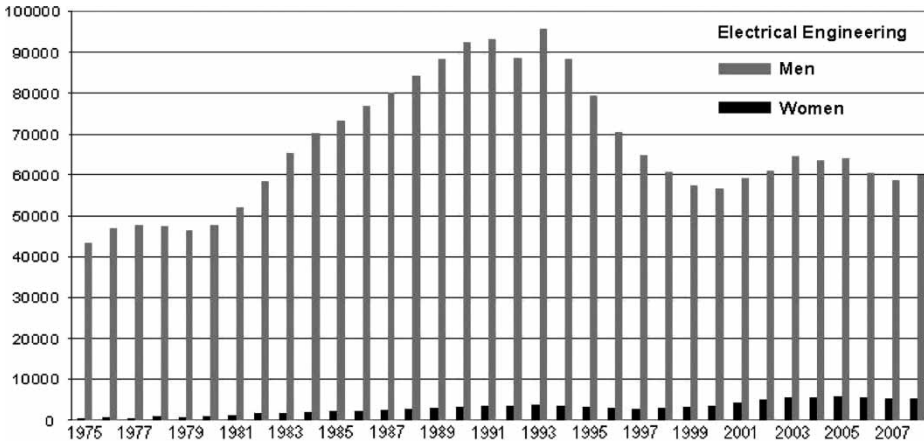


Figure 11. Women enrolled in electrical engineering in Germany. Progress is incremental (VDI).

rather than an expertise point of view! The necessary change of mindset must be initiated at school, but must be effected above all in university engineering departments, where, at least in Germany, even more young women than men drop out.

In addition, the power of perception among young people, which translates into recognition and status in their same-age peer group, cannot be overestimated. Especially during adolescence, self-to-prototype matching is of crucial importance (e.g. Kessels 2005, Taconis 2008, Gräßle 2009, Sjøberg 2010). When defining their gender identity, girls shy away from 'male' jobs and vice versa. This classification is strongly determined by traditions in society, prejudices of parents and teachers (Gras-Velazquez 2009) and the perceived image of a profession, which is shaped largely by often gender-stereotypical youth magazines or soap operas (Dahmen 2009). In TV series or journals preferred by young women, prominent figures are lawyers, fashion designers or doctors, whereas engineers simply do not exist. Thus, young women choose alternative careers (Schwarze 2007, Brinck 2008, Hofmeister 2009), partially based on too rosy expectations.

In light of the fact that women are the largest untapped potential for S&T (Figure 11), 'changing this in the short term would require nothing less than a cultural revolution. Not changing it as soon as it is possible would be a catastrophic loss for humanity' (Tengelin 2009).

8. What do young people really want?

This final section complements the analysis herein with the results of a recently published large-scale survey of 13,000 young people, in which the present author served on the advisory council (NaBaTech 2009). The scope of the study was to gain a more solid database about the attitudes of schoolchildren (3006 respondents), university students (6273) and engineers/scientists (3470) regarding S&T. As a general rule, it can be said that their attitude is positive, even if no specific technology is preferred; a finding that is in line with other studies (Sjøberg 2010). But 'there is a sharp difference between the positive opinion of young people towards S&T and their actual wish to pursue careers in S&T' (OECD 2008). The younger generation's positive attitude does not translate into a willingness to make technology their calling. Only 11% of the students responding wanted to become engineers, another 8% opted for the natural sciences, for the simple reason that the qualities attributed to these professions do not match their wishes, as shown in Figures 12 and 13, which are based on about 2500 answers.

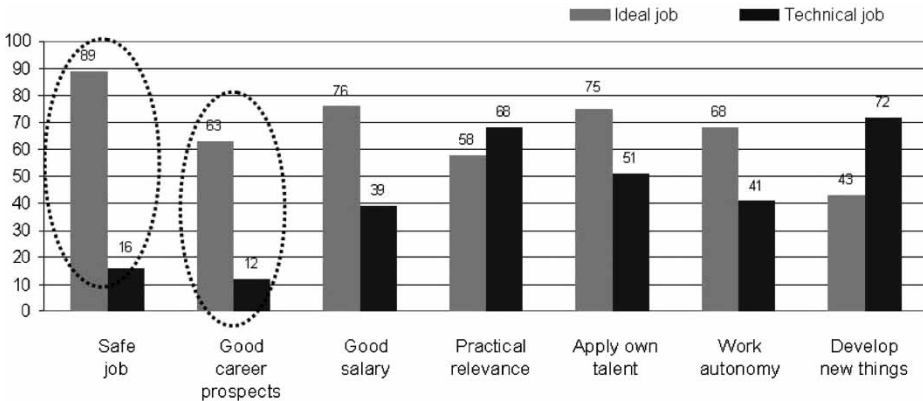


Figure 12. Profile of an 'ideal job' vs. a 'technical job' (NaBaTech 2009).

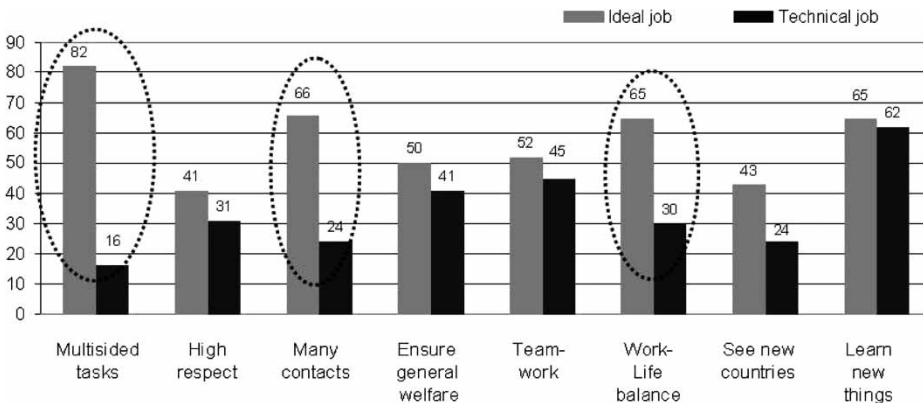


Figure 13. Comparison of qualities desired in an ideal job compared with a technical job (NaBaTech 2009).

The mismatch is especially pronounced (and disturbing) as regards the question of a 'safe job', in spite of the fact that students had been well aware of the positive trend on the labour market during the years 2006–2008! But obviously this good news as well as the predictions of future shortages of engineers was unable to compensate for the bad news of the past. Another reason might be the debate about offshoring even lower level (= possible entry-level) technology jobs to countries such as China and India, where cheaper engineers abound. In addition to this distrust, salaries and career prospects were considered critical as well, a finding in line with the results discussed in section 5.

But even important 'soft factors' desired in an ideal job, shown in Figure 13, differ from those ascribed to technical jobs. As these doubts are obviously to a large extent unfounded (and other professions probably seen in too positive a light), this calls for targeted information campaigns – especially ones presenting role models – to improve the situation.

In this context, some other findings of the NaBaTech-survey may also be mentioned:

- There has been a strong shift in the way children experience technology for the first time. Toys such as trains or construction kits (Märklin, Lego, Fischer-Technik) have been replaced by 'virtual reality' gadgets such as Playstations, the Wii or computer games. This fosters a 'user-attitude' and increases the importance of technology education at schools.

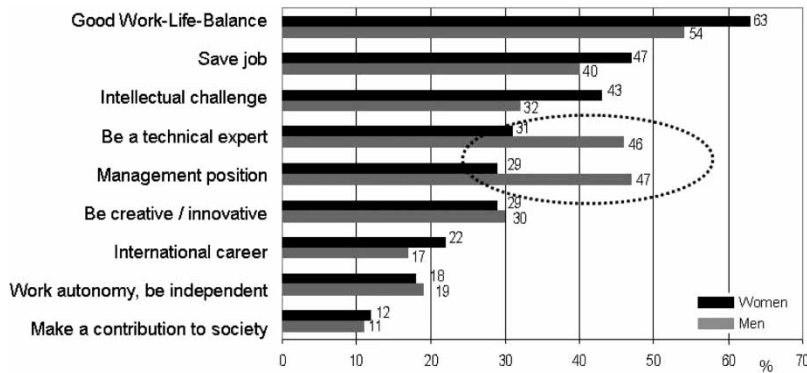


Figure 14. Priorities of German engineering students (3213 male, 1035 female; Universum 2009).

- Even young women with good grades in maths or science are less convinced that they can succeed in engineering. These self-doubts are reinforced by the often arrogant attitude of young men choosing technical subjects for the lack of other options.
- Young women starting engineering are not afraid of being a minority, but two-thirds report discrimination afterwards.
- Young men choosing engineering are fascinated by hands-on technology, but are frustrated by theory-laden and often highly abstract initial study phases.

Finally, these findings are supplemented by the results of a recent survey among about 4200 engineering students. It can be seen that for both genders a good work–life balance and a safe job are high priorities (Figure 14).

The biggest gender difference can be found in career goals, as young men display a distinctly higher eagerness either to become technical experts or to pursue management careers. Interestingly and important for corporate recruiters may be the fact that an ‘international career’ has a low priority. This is an attitude corroborated by other studies (e.g. VDI 2009), where 47% refused categorically to work for a time in, for example, Asia. Also noteworthy is the low motivation, even of young women, to contribute to society, which seems to confirm the ‘technology hermit’ stereotype.

9. Conclusion: What can (and should) be done?

The previous analysis supports the conclusion that young people like technology and do not shun engineering careers just because of laziness or ignorance – they simply do not see it as attractive enough compared with other options. Unfortunately, society and the business world send a host of psychological and financial signals that contradict their claims to foster S&T.

Other trends are contributing to a reduction in the potential supply (OECD 2008). The number of students from blue-collar families, a traditional source of upwardly mobile engineering students, is declining (Hartmann 2009). In addition, the high divorce rates result in more and more children being brought up primarily by their mothers. Since these usually have noticeably less affinity for technology, also through their own upbringing, the children are less motivated to take an interest in technology.

The problem is being further exacerbated by changes in attitude within certain segments of society. Although many of the competition-oriented young have good grades in science, they prefer to embark on careers in insurance or consulting, where the potential rewards are much

more tempting. Young people with a post-materialistic attitude, on the other hand, who value the conservation of nature, are drawn more towards biology or the social sciences; they consider ‘machine technology’ not a solution, but the cause of all problems.

Finally, relatively unattractive teaching methods and a university curriculum that requires students ‘with the persistence of Sisyphus and the patience of Job’, as Shirley M. Tilghman, President of Princeton University, put it recently, frustrates multifaceted students, especially young women. In this environment, the younger generation tries to make the choice that best matches their self-perception – and decides against S&T.

To change this, the deterrents analysed above could be categorised as the following.

9.1. *Technology – can a commodity become a challenge again?*

Technological performance today is determined by ‘invisible’ components such as microelectronics and software, has invaded nearly every aspect of everyday life and has become easy to use. Thus, it is seen as a commodity instead of a challenge – a trend nearly impossible to reverse. As most young people lack the ‘tinkering experience’ at home, schools have a high responsibility as the first (and often only) forum in which hands-on experience with technology is possible. Recommendations include:

- Technology education should be a part of every school curriculum. This requires well-prepared (and paid!) technology teachers, interesting and topical material and continuity – starting in kindergarten and not only after adolescence.
- Guest lectures by scientists and industry researchers could bridge the gap between the school curriculum and the fascinating advances of S&T discussed in the media or seen as products (cars, mobile phones, computers).

9.2. *S&T and society: Basic know-how for informed citizens and a part of every one’s education*

As everyday life is determined by technology, science education should not just aim at producing a few highly qualified experts, but:

Is also about instilling a comprehension of the scientific methods in those who will never oversee a laboratory and giving them a full appreciation of the transformative role of S&T in daily life. Without well-informed policymakers and a discriminating public, scientific progress will be slowed or misdirected, to everyone’s detriment.

(Tilghman 2010)

S&T again has to become an integral part of the knowledge of every educated person. Recommendations include:

- Everyone teaching S&T, from teachers to scientists, should aspire to make these subjects comprehensible, present solutions in a societal context and be willing to engage in discussion.
- Media, from school textbooks to TV, should not present S&T as some remote and male-dominated topic for specialists, but as the foundation of well-being, ignorance of which is a severe deficit, not just a pardonable weakness. One way forward would be to create, for example, a ‘Jules Verne Award’ for the best novel with a technology background.
- Intellectual property rights for technological innovations should no longer be discriminated against compared to those for music and texts (for example, through tax concessions).

9.3. *University education: from stifling to stimulating interest*

For at least four decades (as the author can testify), S&T university professors, in particular, have lamented the inadequate preparation of freshman students and likened their own job to that of erecting pile dwellings in a swamp of ignorance. As a consequence, the first study phase, especially, has been devoted to laying the ‘theoretical foundations’ and to ‘weeding out the weak’. This approach is an effective selection mechanism, but surely not a means to stimulate interest in the subject and prevent those students who doubt their ability to master engineering from dropping out. Extensive studies have shown that a more hands-on approach can yield much better results (Hake 1998), but such findings have remained without impact on most curricula. Recommendations include:

- Shift the focus from even more fundamental research in engineering education to implementation strategies. The top priorities should be best-practice sharing and a subsequent emulation of successful initiatives such as the learning factory (Morell 2007) and project-based learning of the type implemented by Professor Hampe at Darmstadt Technical University (Wolf 2006), which involve freshmen in practical design work.
- Stop emphasising the extremely challenging nature of S&T and the high threshold that must be crossed to achieve an accepted degree. Shift to encouraging and supporting (for example, by introductory courses) the less-gifted and less well-prepared students and train them for the many career possibilities available in addition to technical specialisation.

9.4. *Industry: Enable contacts, highlight the opportunities and improve perspectives*

Companies are places where technology is developed and implemented as well as future employers. They play a crucial role in inspiring the interest of the younger generation and shaping the image of the engineering profession. Recommendations include:

- Dedicate resources to make it possible for students to come in contact with practical work (factory visits, internships, student programmes, presentations by trained experts at schools and universities).
- Highlight the cooperative, problem-solving attitude in engineering, which is a good starting point for graduates to develop their potential. Stop emphasising that only the best are welcome, as most jobs require ‘normal good’ people. Above all, refrain from pointing out that hundreds of thousands of Asian engineering graduates are waiting to work for a fraction of a European salary since the logical conclusion of any intelligent student can only be to avoid such an endangered profession!
- Present role models to exemplify the many positions open to technical graduates and the attractiveness of the work. Improve the career options for engineers beyond the age of 50 years by offering continuous education and challenging projects instead of early retirement.

There is no guarantee that these measures, if applied, will solve the problem, but it is fairly certain that without them the trend away from S&T will continue – and that as a consequence developed societies will be unable to master the challenges of the future.

References

- 4Ing 2009. Viele soziale Aufsteiger unter den Professoren der Ingenieurwissen-Schaften und der Informatik [online]. Available from: <http://www.4ing-online.de/fileadmin/uploads/presse/20100104.pdf> [Accessed June 2010].
- Abbot, A., 2003. *The Zen of education* [online]. Available from: <http://magazine.uchicago.edu/0310/features/zen.shtml> [Accessed January 2010].

- Alpay *et al.*, 2008. Student enthusiasm for engineering: charting changes in student aspirations and motivation. *European Journal of Engineering Education*, 33 (5–6), 573–585.
- Becker, F.S., 2006a. Globalization, curricula reform and the consequences for engineers working in an international company. *European Journal of Engineering Education*, 31 (3), 261–272.
- Becker, F.S., 2006b. Generation 21: What markets require, what active students can do and how a company can help them. Invited paper. *Proceedings of the 34th SEFI annual conference*, Uppsala. ISBN 978-91-631-8387-4
- Becker, F.S., 2009. Why not opt for a career in science and technology? An analysis of potentially valid reasons; paper 131. *Proceedings of the 37th SEFI annual conference*, Rotterdam 2009. ISBN 978-2-87352-001-4
- Brinck, C., 2008. Die Freiheit, sich gegen den Ruhm zu entscheiden. *Frankfurter Allgemeine Sonntagszeitung*, 8 June.
- Butz, W.P. *et al.*, 2004. *Is there a shortage of scientists and engineers? How would we know?* [online]. Available from: http://www.rand.org/pubs/issue_papers/IP241/index.html [Accessed January 2010].
- Dahmen J. and Thaler A., 2009. Image is everything – is image everything? *Proceedings of the 37th SEFI annual conference*, Rotterdam. ISBN 978-2-87352-001-4
- Eisen, B., 2009. *Inside higher ed* [online]. Available from: <http://www.insidehighered.com/news/2009/07/22/stem> [Accessed January 2010].
- EU 2006. *Women in science and technology – the business perspective*. Report EUR 22065 EN. Brussels: European Commission. http://www.businessupdated.com/shownews.asp?news_id=1354&cat=women+in+science+and+technology:+the+business+perspective [Accessed June 2010].
- EU 2008. *Young people and science*. Flash Eurobarometer Series 239. Brussels: European Commission.
- Fabian, G. and Briedis, K., 2009. Aufgestiegen und erfolgreich. Ergebnisse der dritten HIS-Absolventenbefragung. *HIS-Forum Hochschule*, February, 65.
- Gago, J.M., 2004. *Europe needs more scientists*. Report by the High Level Group on Increasing Human Resources for Science and Technology in Europe. ISBN 92-894-8458-6
- Gerlach, G., 2007. Die Situation ist in der Tat bizarr. *Markt und Technik*, 30 March, 52.
- Goossens, M., 2007. Where is the shortage of engineers in Europe coming from? A historical perspective. *SEII Round Table conference*, 9 November 2007. Official report. 23–31. <http://www.nuttin.info/SEII/doc/Report-TRI.pdf> [Accessed June 2010].
- Gräble, K., 2009. *Frau Dr. Ing. – Wege ebnen für Frauen in technische Studiengänge*, Leverkusen. ISBN 386649243X
- Gras-Velazquez, A. *et al.*, 2009. *White paper women and ICT* [online]. European Schoolnet. Available from: <http://seskills.eun.org> [Accessed January 2010].
- Hake, R., 1998. Interactive-engagement vs. traditional methods: A 6000 student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66 (1), 64–74.
- Hartmann, M., 2009. Stellen die Ingenieurwissenschaften noch den Karriereweg für soziale Aufsteiger dar? In: M. Nagl, *et al.*, (Hrsg.) *Zukunft Ingenieurwissenschaften – Zukunft Deutschland*. Berlin: Springer Verlag, 191–199.
- Henning, K., 2007. Bachelor nach rheinischer Art, *Die Zeit*, 25 October 2007.
- Hofmeister, H., 2009. Warum verzichten wir auf 40% unserer Kreativen? In: M. Nagl *et al.*, (Hrsg.) *Zukunft Ingenieurwissenschaften – Zukunft Deutschland*. Berlin: Springer Verlag, 177–189.
- IW, 2008. *Ingenieurmangel: Übel an der Wurzel packen* [online]. IwdNr. 9, 2008. Available from: <http://www.iwkoeln.de/tablID/2204/ItemID/21933/language/de-DE/default.aspx> [Accessed January 2010].
- Johnson, W.C. and Jones, R.C., 2006. Declining interest in engineering studies at time of increased business need. In: L.E. Weber and J.J. Duderstadt, eds. *Universities and business: Partnering for the knowledge society*. London: Economica, 243–252.
- Kessels, U., 2005. Fitting into the stereotype: How gender-stereotyped perceptions of prototypic peers relate to liking for school subjects. *European Journal of Psychology of Education*, 20 (3), 309–323.
- Kogon, E., 1976. *Die Stunde der Ingenieure*. Düsseldorf: VDI-Verlag.
- Meyer, T., 2008. *Deutsche Bank Research: Mint-Fachkräfte – Zwischen zyklischem Engpass und Strukturwandel*. Report, 16.7.2008.
- Minks, K.-H., 2005. Kompetenzen für den globalen Arbeitsmarkt: Was wird vermittelt? Was wird vermisst? In: Grünberg/Wenke (Hrsg.), *Arbeitsmarkt Elektrotechnik Informationstechnik*, 29–48. ISBN-13: 978-3800728961
- Minks, K.-H. and Fischer, L., 2007. Acht Jahre nach Bologna – Professoren ziehen Bilanz, HIS Projektbericht, October 2007.
- MoMoTech 2009. *The future of scientific and technological professions and the conditions for an improved public understanding of science and technology* [online]. Available from: http://www.dialogik-expert.de/en/forschung/projektverbund_zukunft.htm [Accessed January 2010].
- Morell, L., 2007. Engineering education, globalization and economic development: capacity building for global prosperity. In: W. Aung *et al.*, ed. *World innovations in engineering education and research*. New York: iNEER, Begell House Publishing, 25–43.
- NaBaTech 2009. *Nachwuchsbarometer Technikwissenschaften* [online]. Available from: <http://www.acatech.de/de/projekte/laufende-projekte/nachwuchsbarometer-technikwissenschaften-nabatech.html> [Accessed January 2010].
- Nair, C.S. *et al.*, 2009. Re-engineering graduate skills – a case study. *European Journal of Engineering Education*, 34 (2), 131–139.
- OECD 2007. Report education at a glance. ISBN: 978-9264032873
- OECD 2008. Encouraging student interest in science and technology studies. ISBN: 978-92-64-04069-4
- Pallesen 2007. *DTU-rektor: Ingeniørmangel er klynk* [online]. Available from: <http://ing.dk/artikel/77777-dtu-rektor-ingeniørmangel-er-klynk> [Accessed January 2010].
- Prieto, E. *et al.*, 2009. Influences on engineering enrolments. A synthesis of the findings of recent reports. *European Journal of Engineering Education*, 34 (2), 183–203.

- Pritschow, G., 2004. Herausforderung als Chance. *Tagungsband zum acatech-Symposium, 'Innovationsfähigkeit'*, Berlin, 11 May 2004, 50.
- RAND 2004. The US scientific and technical workforce. http://www.rand.org/pubs/conf_proceedings/2005/CF194.pdf [Accessed 4 June 2010].
- Reisach, U., 2010. Macht und Machtmissbrauch. *Personalwirtschaft*, February, 22–24.
- Schmauder, S., 2004. Fachwissen ist und bleibt Basis für die Ingenieurkarriere. Grüneberg/Wenke (Hrsg.) *Arbeitsmarkt Elektrotechnik 2004*, 69–77. ISBN-13: 978-3800728992
- Schwarze, B., 2007. Ingenieurinnen in Studium und Beruf – zwischen Herausforderungen, Stereotypen und Berufsen-gagement. *Das Berufsbild der Ingenieurinnen und Ingenieure im Wandel*. VDI-report 37.
- Sjøberg, S. and Schreiner, C., 2010. The next generation of citizens: attitudes to science among youngsters. In: M. Bauer, N. Allum and R. Shukla, eds. *The culture of science – How does the public relate to science across the globe?* New York: Routledge.
- Staudt, E., 1998. *Strukturwandel und Karriereplanung, Herausforderungen für Ingenieure und Naturwissenschaftler*. Berlin: Springer Verlag, 4.
- Taconis, R. and Kessels, U., 2008. How choosing science depends on student's individual fit to 'science culture'. *International Journal of Science Education*, May, 1115–1132.
- Tengelin, N., 2009. *Corporate investment to increase interest in mathematics, science and technology*. A general analysis for the Volvo-group. Thesis (Master). Report No. E 2009:093. Chalmers University Sweden.
- Tilghman, S.M., 2010. The Future of Science Education in the Liberal Arts College. Speech given as President of Princeton University at the Presidents Institute Annual Meeting, Florida, 5 January 2010.
- Universum 2009. Universum student survey.
- VDE 2000. Studie Ingenieure der Elektro- und Informationstechnik.
- VDE 2007. Studie 'young professionals 2007' (in German).
- VDE 2009. Studie 'young professionals 2009' (in German).
- VDI 2009. VDI nachrichten Studie Ingenieureinkommen 2009. In Germany, the salaries of standard wage earners working in the thriving energy sector, if adjusted for inflation, showed a slight decrease between 1997 and 2007!
- VDI 2010. Extensive data to be found at <http://www.vdi-monitoring.de/index4.php>
- VDI 2010. Ingenieure haben weniger Kaufkraft als vor 10 Jahren. VDI nachrichten, 15 January 2010.
- VDMA 2007. *Impuls survey 'Anforderungen an die Promotion im MB und der Verfahrenstechnik'*, Frankfurt 2007 [online]. Available from: www.impuls-stiftung.de [Accessed January 2010].
- VDMA 2009. *Impuls survey, Zwischen Studienerwartungen und Studienwirklichkeit – Gründe für den Studienabbruch* [online]. Available from: http://www.his.de/pdf/21/studienabbruch_ursachen.pdf [Accessed January 2010].
- Winckler, G. and Fieder, M., 2006. Declining demand among students for science and engineering? In: L.E. Weber and J.J. Duderstadt, eds. *Universities and business: Partnering for the knowledge society*. London: Economica, 233–241.
- Winkler, H. et al., 1996. VDI-Studie Ingenieurbedarf, Universität Gesamthochschule Kassel, 30 June 1996.
- Wolf, S. and Hampe, J.M., 2006. How to provide first-year students with a really good start to their study program. *Proceedings of the ASEE annual conference*, Chicago, June 2006.
- ZVEI 1987. Erfahrungsbericht des ZVEI auf der CeBit-Messe, Protokoll vom 12 October 1987. http://www.zvei.org/de/forschung_bildung/ingenieurausbildung/statistik.

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