NATIONAL SURVEY | SUMMARY

Nachwuchsbarometer Technikwissenschaften

Careers in Science and Engineering: Trends, Expectations and Attitudes of Young People




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Nachwuchsbarometer Technikwissenschaften

The „Nachwuchsbarometer Technikwissenschaften“(Barometer) was jointly proposed to the Federal Ministry for Education and Research (BMBF) by acatech and VDI, and the BMBF provided the necessary funding. The University of Stuttgart (Prof. Dr. Dr. h. c. Ortwin Renn and Dr. Uwe Pfenning) was responsible for the academic research concept and its empirical implementation. The target groups of the in-depth surveys were school pupils, students, engineers and natural scientists – both male and female in each case.

This short version of the results of the „Nachwuchsbarometer” concentrates on the main initial findings and the conclusions from empirical surveys (from August 2008 to January 2009) of 3,500 pupils (with and without technology instruction), around 6,500 students (including a control group) and a member survey of eight engineering and natural-science associations (approx. 3,200 respondents).

FOREWORD

NACHWUCHSBAROMETER TECHNIKWISSENSCHAFTEN

APPENDIX

FOREWORD
acatech and VDI

Prof. Dr.-Ing. Joachim Milberg

Dr.-Ing. Willi Fuchs

Germany is threatened by a shortage of skilled workers in the fields of mathematics, information science, natural sciences and engineering that can have severe consequences for the innovative capacity of science and business. Consequently, the declared aim of acatech and VDI is to promote a sustained interest in natural-science and technical careers and to increase the numbers of persons who earn corresponding qualifications. A lack of qualified young professionals in the applied and natural science fields will significantly impact Germany's economic growth and the quality of life of German citizens, unless society takes decisive action today to counter this trend on the basis of reliable information.

But what exactly are the reasons for the shortage of young people in technical and natural-science courses of study and careers? Are these careers not attractive enough? Are we not finding the right approaches to stimulate curiosity and awaken and continuously promote young peoples' interest in technology and the natural sciences? What are the best ways to encourage young people to choose technical and natural-science careers in the long term?

These questions are not new. Many initiatives and institutions have been working on them for years, but the offerings for encouraging technical career choices have to date not been sufficient to really prevent a shortage of academically trained engineers. acatech and VDI believe that both biographical and structural issues need to be pursued in an integrated manner if young people are to be successfully encouraged to choose technical and natural-science careers. To this end, the Applied Sciences Youth Barometer was initiated at the end of 2007 with the financial support of the Federal Ministry of Education and Research. A research team from the University of Stuttgart conducted a wide-ranging empirical survey on this issue in close cooperation with acatech and VDI. We would like to express our sincere gratitude to all employees, as well as to the volunteer project advisory council.

The results of the "Nachwuchsbarometer Technikwissenschaften" provide important empirical findings regarding technological socialisation and technological education in Germany, and thus offer a well-founded basis for developing a systematic approach to promoting young peoples' career choices. The Barometer provides guidance and information on major interrelated life phases of children, youths and young adults as well as on the context and influence potential of the home, school, career counselling and orientation offerings, higher education, business and politics. We hope that our joint recommendations provide a strong basis for further advancing the many good approaches for promoting young people.

Prof. Dr.-Ing. Joachim Milberg

Member of the Executive Board,
acatech – German Academy
of Science and Engineering

Dr.-Ing. Willi Fuchs

Director
VDI
Association of German Engineers

GREETING

THE FEDERAL MINISTER OF EDUCATION AND RESEARCH

Education and research are the source of our future prosperity. That is why, particularly in economically difficult times, we must provide all individuals in our country the best possible opportunities to develop their abilities and to improve and expand their qualifications and skills through life-long learning. The creativity and productivity of highly qualified experts is the key to resolving the challenges of today and tomorrow.

To ensure that Germany remains a global leader in terms of its technological capabilities, the natural and applied sciences must be recognised by all segments of society as drivers for innovation and sustained growth. This is also the goal of the Science Year 2009. Under the motto “Research Expedition Germany”, the Science Year is making an important contribution toward eliminating prejudices and communicating the fascination inherent in the natural and applied sciences to society at large. We particularly want to stimulate young people's enthusiasm for the applied sciences and offer them attractive perspectives for realising their own life opportunities. This is the only way that Germany can utilise its opportunity to emerge from the crisis even stronger than before.

With the qualification initiative “Advancement through Education”, the federal government has laid the groundwork for securing the base of skilled workers in Germany over the long term.

We are enhancing education opportunities in all life phases – early childhood education, school and vocational training, higher education and continuing career education. One important aspect is encouraging young people to choose careers in the applied and natural sciences. Initiatives such as the “Pakt für Frauen in MINT-Berufen” [Joint Initiative for Women in MINT (Mathematics, Informatics. Natural Sciences and Technology) Professions] are intended to encourage young women in particular to choose a career in these promising professions.

The Applied "Nachwuchsbarometer Technikwissenschaften" provides important insights for the political, business and academic spheres to advance this process further.

All parties involved have a duty to work together to overcome the skills shortage in the applied sciences. The recommendations for action presented here provide the persons responsible with the necessary support and expertise.

Prof. Dr. Annette Schavan, MdB
Federal Minister of Education and Research

ABSTRACT

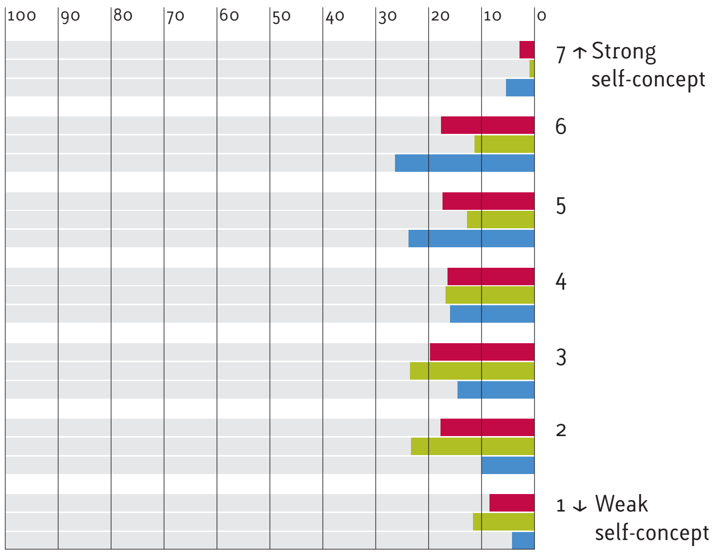
Good technology instruction has been proven to promote individual interest in technology.

Successful technology socialisation, i.e. obtaining an early understanding of the functions, potential and opportunities of technology, and the risks it poses, begins at home. By promoting fun and curiosity through a playful, experimental approach to technology and natural science, it is possible to awaken an interest in technological matters while engendering greater openness toward technology. It is already clear today that traditional technical toys such as building blocks are declining in importance, while computer-based applications are being adopted in early childhood. Overall, however, the playful exploration of technology and natural sciences by children and parents together is declining. This may be explained primarily through a change in the preferred toys (computerization), different experiences with technology from one generation to the next, and a concurrent loss of technology associations in everyday experience. For this reason, institutional technology education in schools is becoming ever more important for successful technology socialisation compared to individual technology education at home, the aim being to compensate for the lack of technical experience acquired in the home. School instruction is poorly equipped for this task. From the perspective of the pupils, promoting technical and scientific knowledge does little to stimulate an individual interest in technology or develop pupils' own corresponding gifts. For one thing, technology instruction is not offered universally, and above all not continuously, in German schools. This is a mistake. As the results of the "Nachwuchsbarometer" reveal, good technology instruction demonstrably improves individual technology interest. Another issue is that even where the curriculum includes technical topics, many pupils consider the equipment and didactic structure of technology instruction as being in particular need of improvement. In those institutions in which little or no technology instruction is offered, physics plays a key role as the "gateway" subject for technology and the choice of a tech-nical course of study or career. On average, however, the pupils surveyed described physics instruction as far removed from technology and practice. Particularly for girls, a positive self-assessment of one's own technical and scientific knowledge and abilities (self-concept) is also important. Mathematical understanding and knowledge, however, are less relevant for the study or career choices of pupils with a technical interest. That is one of the surprising findings of this study.

Figure 1

TECHNOLOGICAL SELF-CONCEPT, PROPORTIONS OF MALE AND FEMALE STUDENTS

Cumulative index from multiple questions



Total
Female
Male

n pupils (m/f): 3,007

Percentage values // Year → 2009 // SOURCE → "Nachwuchsbarometer Technikwissenschaften", own calculations

Although individual key experiences awaken an interest in technology and natural sciences, this interest must be nurtured through appropriate ongoing technology education offerings if the motivation is to be sustained. From this, we may derive three important factors that increase the probability that young people will develop an interest in technology and discover their individual talents for a technical career: firstly, an early encounter with and playful exploration of technology; secondly, individual key experiences in which technology is experienced as interesting and challenging (e.g. science centres, technology shows such as the "IdeenPark" (Ideas Park), hands-on laboratories and more); and thirdly, continuous, didactically well-conceived technology education in schools. This can occur within the framework of a separate "technology" class, but also in the context of related subjects like physics or proficiency training. However, the significance of key experiences is also an indication that early education alone is insufficient for maintaining a sustained interest in technology in the long term.

The topic of career information does not receive sufficient attention. The study results show that internships in particular are popular with both pupils and students as they enable young people to form their own impressions of the career landscape and compare the requirements of a particular career with their own abilities.

Career information is also considered a task of the schools (see the BOGY programme in Baden-Württemberg). This is because at school, young people not only acquire factual knowledge but also form their conceptions of technology and science, and thus of the associated careers. All target groups view school-level career information as largely negative.

The „Nachwuchsbarometer" study revealed major and profound differences between expectations and experiences with respect to a degree course in engineering and natural sciences. The expectations of pupils are often more positive than the concrete experiences of students. Disappointed expectations lead to frustrations and to motivational crises in the event of setbacks in the course of study. In the worst case, they can cause students to drop out or change their course of study. One decisive reason for this could be that apparently very few realistic conceptions of the actual requirements of a course of study in engineering and the job profiles of engineering professions are available to young people in the career or study orientation phase before or after completing school.

The data of the Barometer indicate that a variety of reasons lie behind the choice of a course of study on the part of different groups. Thus, there are upper secondary school graduates who choose their course of study more for materialistic reasons (income, advancement opportunities, job security, etc.) and associate these expectations with technical professions, as well as young people commencing their studies who choose such a course for intrinsic reasons (realizing their talents, pleasure in the work, self-realization in the career, etc.). Many also mix these extrinsic and intrinsic motives and make their decision on the basis of complex situational reasons. Such reasons include the perceived situation on the labour market or the anticipated job security in the intended profession. These are the findings of the studies of the Higher Education Information System HIS.

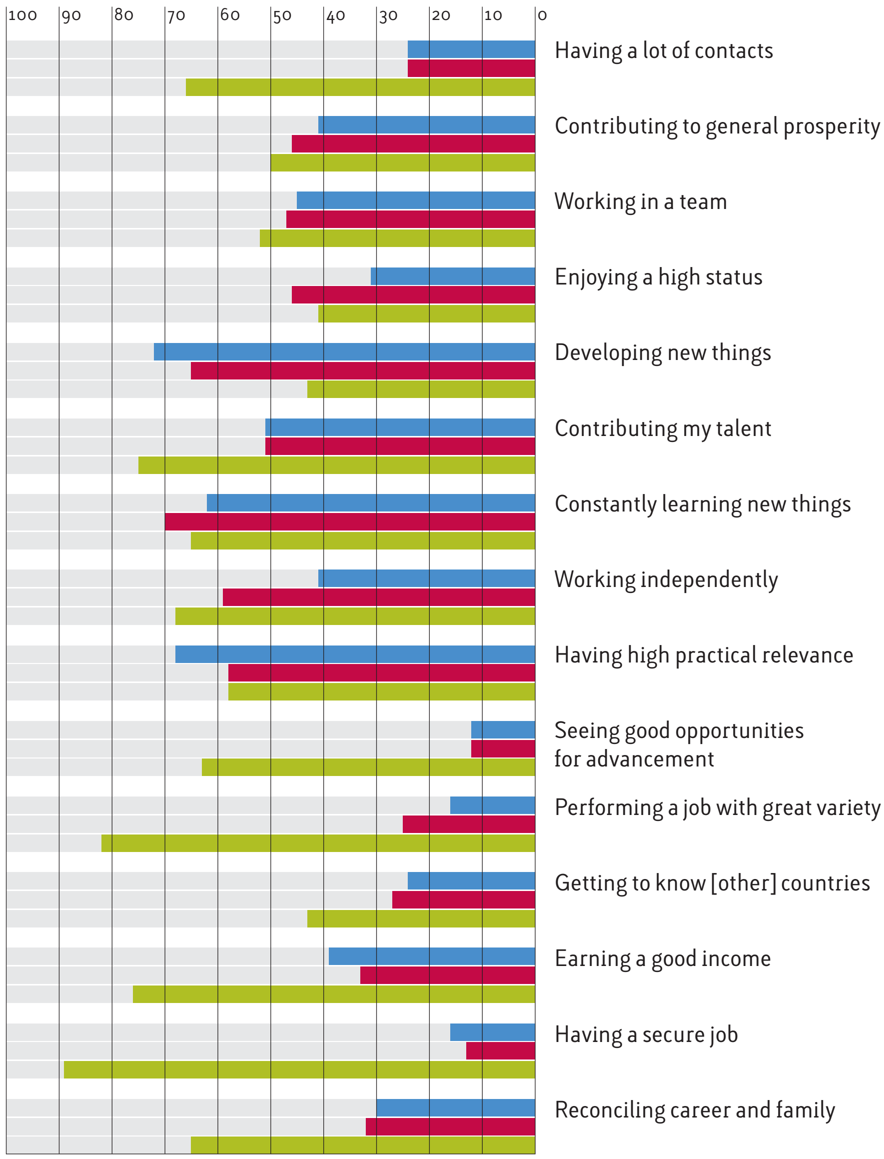
In contrast to the impression of a negative image of the engineering profession often propagated by the media, these surveys reveal that young people have more of a positive conception of technical professions. Technical professions are associated with such attributes as "modern", "progressive" and "useful". The contribution of technical research to the development of humanity is also viewed as positive. Economically related attributes such as "creating jobs" and "serving consumption" also find a high positive resonance. Image weaknesses of technical careers include a lack of creativity, possible risks and the lack of communication of their social contributions. In spite of the predominantly positive image of these professions, technical courses of study and careers are seldom chosen, even by pupils with an exceptional interest and high qualification in this direction. Just under half of all pupils with an exceptional interest in technology and natural science choose a course of study in the mathematics, information technology, natural sciences and engineering fields. This reveals the problematic development that those who decide against studying natural science or technology in spite of their exceptional talents are convinced that these courses are complex, demanding and highly risky, while those who choose these courses of study tend to underestimate the demands.

Attractive technology instruction demonstrably promotes interest in technical careers.

Figure 2

COMPARISON OF CHARACTERISTICS OF THE IDEAL CAREER WITH CHARACTERISTICS OF TECHNICAL AND NATURAL-SCIENCE CAREERS

"How important are these motives for you in choosing a career?"



■ Technical careers
■ Science careers
■ Ideal career

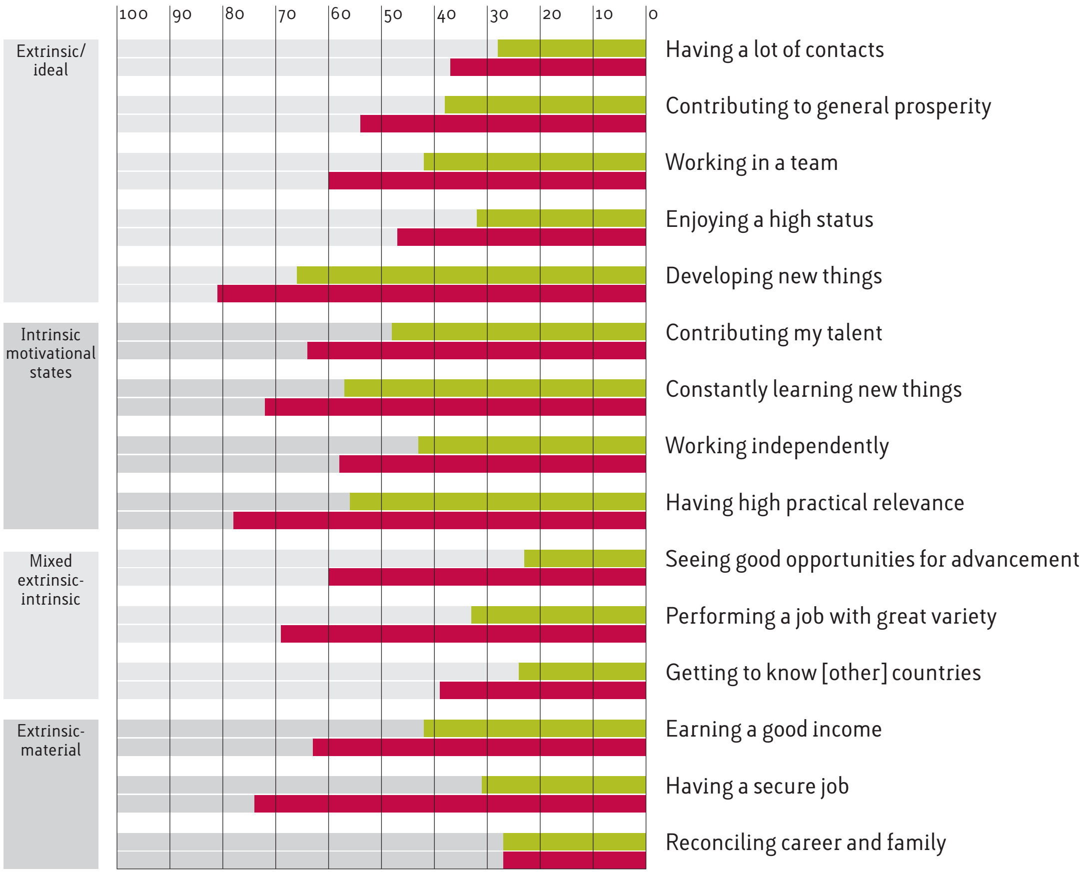
n pupils (m/f): 2,350 to 2,780 cases for the various characteristics (total: 3,007), responses for the answer categories "very important" and "extremely important" have been combined.

Percentage values // Year → 2009 // SOURCE → "Nachwuchsbarometer Technikwissenschaften", own calculations

Figure 3

IMAGE PROFILE OF TECHNICAL CAREERS FOR MALE AND FEMALE PUPILS WITH TECHNICAL CAREER GOAL AND STUDENTS OF TECHNICAL DISCIPLINES

“What characteristics do the following careers have in your opinion?”



Pupils (m/f)
Students (m/f)

n pupils (m/f): 2,700 to 2,852 cases for pupil sample (total: 3,007)
n students (m/f): 4,231 to 4,872 cases for student sample (total: 6,253)

Percentage values // Year → 2009 // SOURCE → “Nachwuchsbarometer Technikwissenschaften”, own calculations

Young women continue to show especially little interest in natural-science careers – even those who appear particularly suited for such professions on the basis of their school performance. The primary reason for this is that they perceive the career profile as interesting but the working environment as male-dominated. Consequently, they see too few opportunities for contributing their own skills. Additionally, individuals’ perception and appreciation of their own skills presents gender-specific characteristics: compared to boys, girls show a less pronounced technical self-concept (i.e. estimation of their own capabilities in connection with technology) and have more doubts about their own talents. Although this finding is not new, effective solutions for motivating talented girls to take up engineering studies and careers are still lacking.

What urgent recommendations can be derived from the summarized results? In order to enable the sustained nurturing of existing interests, ongoing technology education should be offered in schools either as a separate subject or as separate lesson units in proficiency training and science classes. Didactically attractive technology instruction has been shown to promote interest in technology and the associated careers. Additionally, pupils should be offered continuing and realistic academic and career counselling with a close correspondence to practice. Career-related internships offer an excellent opportunity to close the gap between the expectations of higher education and career and the actual conditions. The offerings should be highly varied in order to accurately reflect the wide range of technical careers as well as the corresponding motivational situations of pupils and students.

Just like pupils, many students would also like to see greater practical relevance. The study reveals a clear discrepancy between the expectations of the course of study on the part of first-semester students and the actual experiences described by the university graduates. The institutes of higher learning should do more to fulfil the desire for more practical authenticity. One key task here is not to confuse professional practice with practical applicability in the sense of experiments, projects and hands-on technologies. Both levels are essential.

The „Nachwuchsbarometer“ provides further indications that female pupils and students are still confronted with disadvantages, i.e. external obstacles, that make it difficult for them to realize their interests. Additional efforts are needed to motivate talented and interested young women to choose technical studies and careers. This objective is obstructed in the first place by structural barriers: structural disadvantages such as lower income or greater risk of unemployment are perceived by girls and women and have a clear impact on the choice of their course of study. The comparison of individual expectations and structurally/institutionally communicated experiences under everyday study and career conditions indicates a high frustration potential due to real disadvantages, particularly for women. Our recommendation is thus to improve real working conditions for women. Family-friendly working conditions are also being valued more and more by men.

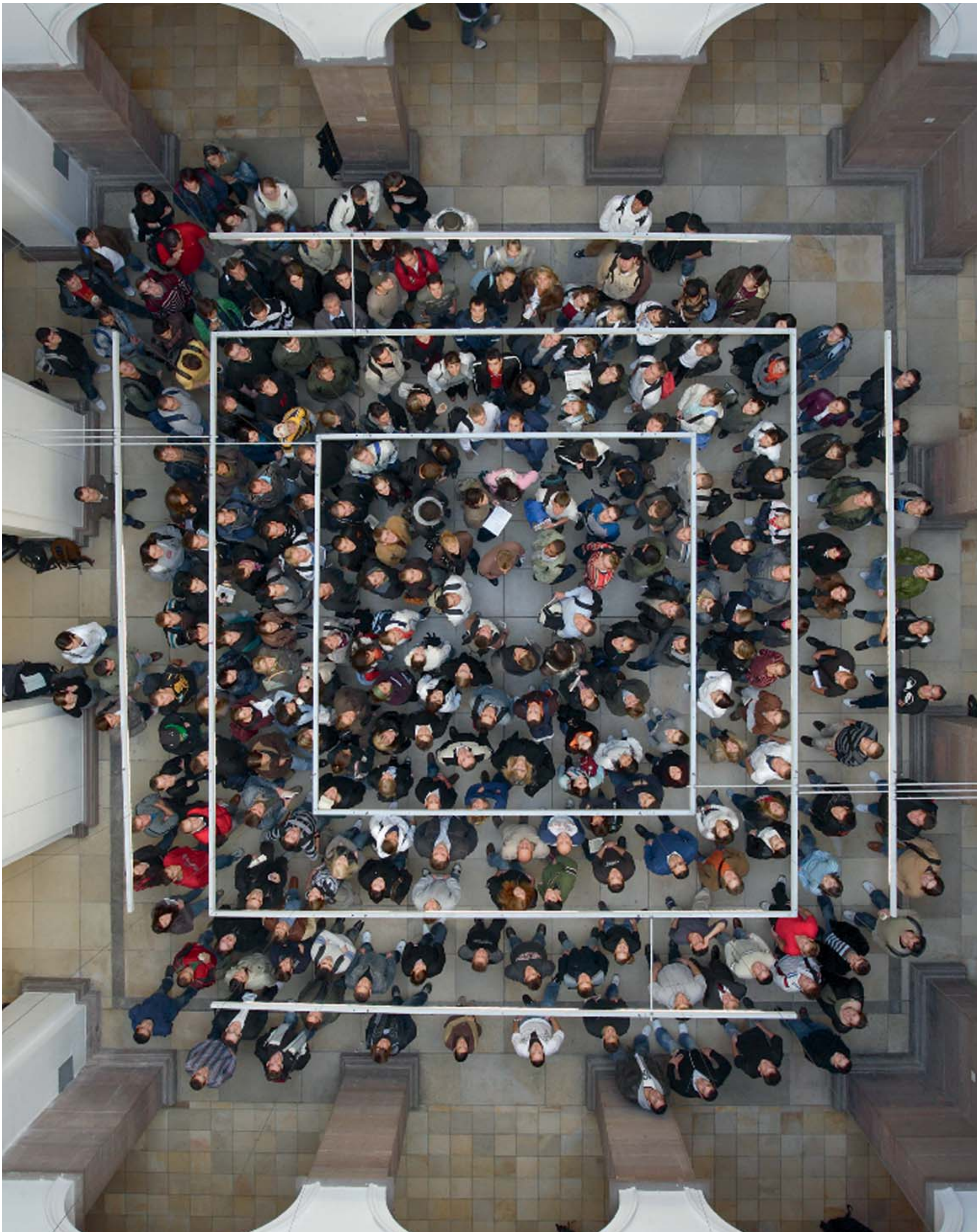
The real working conditions of women should be improved.

Secondly, there are motivational obstacles. Individual pedagogical strategies (mentoring programmes, the occasional use of monoeducational teaching forms) help here. Such individual attention, however, cannot compensate for the equally powerful disadvantages presented by the social self- and external images of women and technology. This study demonstrates that social prejudices (“Girls aren’t as interested in technology as boys,” “Most boys understand technology better than girls”) prove to be extremely durable and additionally (in the comparison between samples of female pupils, male pupils and students as well as the control groups) are disproportionately present in the male representatives of these academic disciplines. Thus, breaking down the stereotypical conceptions and expectations with respect to women in technical professions remains an important task, as otherwise individual assistance will achieve little. The extent to which greater proportions of women will “feminize” the understanding of technology and the prejudices will die out is an interesting question, but one which lies outside of the analytical capabilities of the Barometer.

Ultimately, the findings form the basis for requiring that the social context of technology with its positive contributions and possible risks for the economy, day-to-day life, culture and politics be discussed much more intensively than has been the case to date in schools and universities. The aim should be to attain individual technology competence, i.e. the capability of arriving at a balanced assessment of technology in the economy and society on the basis of well-founded knowledge and individual values. This includes on the one hand a fundamental openness toward technology, and on the other an integrative understanding of technology as an element of a modern, distributed, innovation-based culture. Technological competence is increasingly becoming a prerequisite for participating in technical-economic as well as political-social life.

THE STUDY

“NACHWUCHSBAROMETER TECHNIKWISSENSCHAFTEN”



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From August 2008 to January 2009, the research team of the University of Stuttgart surveyed pupils, students and members of eight professional associations and engineering and scientific organizations throughout Germany using written, and in some cases also online, questionnaires. The questions targeted pupils in classes 8 through 13 (3,007 in all) at schools with and without technology instruction, first-semester students and students in advanced semesters at institutes of higher learning, differentiated according to innovative and traditional academic programmes (6,253 in all), as well as employed and unemployed engineers and scientists (3,586 in all).

THE FUNDAMENTAL OBJECTIVES OF THIS STUDY ARE:

- Determining the technology understanding of male and female pupils and identifying their sources (mental associations, image of courses of study and technical and scientific careers, role of parents and teachers and of the institutions).

- Analysis of attitudes toward technology and natural sciences with respect to perceived individual technology competence, interest in technologies and natural sciences and the significance of social trends for individual academic and career choices.

- Delineating the primary and secondary technology socialisation of male and female pupils, students, engineers and scientists at home and at school as well as analyzing these for differences in individual technology biographies in an intergenerational comparison between respondent groups. This enables, for example, an analysis of whether older engineers received different childhood learning experience with respect to their technological interests and their capabilities and skills compared to what present-day pupils receive from their parents.

- Comparison of expectations and experiences of the respective target groups with regard to motivational states, image profiles of degree courses and careers and the quality of teaching and career training, so as to identify potential conflicts where great discrepancies exist and derive the necessary conclusions for realistically communicating the academic and career requirements and stimulating a discussion of innovative didactic reforms for secondary and higher-education instructions.

This study also attempts to assess the state of prior research and summarize previous studies. In view of the many and often contradictory lines of research and their correspondingly divergent results, this is – given the circumstances – an ambitious and sometimes provocative challenge.

The "Nachwuchsbarometer" considers not only the engineering professions, but also the natural sciences, mathematics and information science, for in view of the wide variety and interdisciplinary nature of the professions, it is interesting to learn with what other career preferences the engineering disciplines are competing.

The focus of the Barometer is on observing processes, developments and trends. Analogous to a physical measuring process, the Barometer measures the demand for careers in the mathematics, information technology, natural sciences and engineering fields. One fundamental assumption of the „Nachwuchsbarometer" is that engineering and natural sciences are communicated individually through a long-term social process that is certainly subject to the influences of individual experiences. This has both methodological and pragmatic implications: many of the goals enumerated above ought to be tracked and observed in multiple surveys over a long period. No such studies exist, as they would be expensive and the results only usable after a long period. However, these studies remain the empirical ideal of necessary data surveys concerning the status and development of technological and scientific professions and careers.

In view of the shortage of trained specialists mentioned above, the „Nachwuchsbarometer" was intended to provide results on which to base initial action recommendations within a comprehensible timeframe. Consequently, many data points respecting early technology socialisation have been collected retrospectively, i.e. the respondents were asked about past experiences that influenced their choice of study or career. An additional aim was to determine whether the associated surveys can be realized for the three target groups under financial and time constraints.

The question of the feasibility of a Barometer for engineering and natural sciences at appropriate expense is significant for permanently establishing an instrument of this type to monitor such important professions for the German economy and for academic and scientific policy advice.

The focus of the "Nachwuchsbarometer Technikwissenschaften" is on observing processes, developments and trends.

The „Nachwuchsbarometer" brings together many aspects for discussion of the future of technical and natural-science professions. Consequently, it can offer only descriptions of a number of aspects, but is still able to provide a weighting of many constructs with respect to one another. The Barometer is conceived as an empirical core that is designed to be complemented by further specialized studies on open research questions.

The main areas of research (constructs) were: technology socialisation, technology education, communication of technology, associations with technology and natural sciences, benefits of technology, individual perceptions of social developments in the academic and labour markets, interest in technology and natural sciences and determinants for the choice of career and study. Additionally, the relevant sociodemographic features were obtained (gender, age, educational biography, career biography, parents' occupations).

SUMMARY
INTERPRETATION OF RESULTS

In Germany, young people with a talent and interest in technology and natural sciences receive too little support in spite of a plethora of new support programmes and projects. This begins in the home. In view of changing technology, rapid knowledge cycles and the increasing digitization of technology, many parents seem out of their depth when confronted with the relevant early-childhood rearing of their children. The traditional motivation via building blocks, experiment kits and model railroads, as well as exploring and repairing technical objects (in the home) is virtually absent among modern youth. No corresponding substitute forms of motivation can yet be identified in the home; early computer use, which is apparent everywhere, appears to increase technology consumption rather than stimulating an interest in and curiosity about how technology functions. In this context, institutional technology socialisation in the form of technology education is gaining in importance.

From the pupils' perspective, the promotion of interest in technology in the schools is insufficient. They generally experience the lessons as rather boring and thus offering little motivation. Additionally, they rate the classroom equipment as inadequate. However, the results of the „Nachwuchsbarometer" show the important role the schools play in awakening and sustaining young peoples' interest in technology: technology instruction in school significantly increases interest in technologies. Good technology instruction thus increases the likelihood that a technically talented pupil will want to take up a technical career, and makes disinterested pupils more likely to explore technology. Above all, there is a lack of discussion of the economic and social contributions and consequences of technology for the economy, public welfare, culture, politics and day-to-day life. Particularly these consequences are important topics for girls interested in technology. An important opportunity is being wasted here.

Table 1

TECHNICAL AND SCIENTIFIC INTEREST
OF MALE AND FEMALE PUPILS

"How interested are you right now in… ?"

Subject	w/ technology instruction	w/o technology instruction
… Mathematics	2,66	1,89
… Physics	2,31	1,75
… Biology	2,46	1,87
… Chemistry	2,27	1,76
… Information science	2,44	1,87
… Computer technology	2,76	1,92
… Electronics/electrical engineering	2,54	1,85
… Mechanical engineering	2,29	1,84
… Renewable energy sources	2,24	1,78
… Genetic technology	2,09	1,75
… Aerospace	2,05	1,82

1 = very low
2 = somewhat low
3 = somewhat high
4 = very high
5 = extremely high

n: 188 to 836 cases

Mean values // Year → 2009 // SOURCE → Applied Sciences Youth "Nachwuchsbarometer Technikwissenschaften", own calculations

Discontinuities in technology socialisation and between expectations and experiences can be identified at two points in the educational system. On the one hand, there is a discontinuity at the transitions between home, kindergarten and school, when children who have obtained a grounding in technology from their parents do not receive a corresponding offering (i.e. technology instruction) at school. Conversely, for many pupils, technology education does not begin until the higher school classes, particularly during the onset of puberty. At this point, however, education must compete with young peoples' leisure behaviour and is thus less effective.

The second discontinuity occurs at the transition from secondary to higher education. Expectations and experiences diverge greatly here with regard to technology. The academic demands tend to be underestimated, which produces experiences of frustration that are reflected in the high rate of university drop-outs. Above all, individuals commencing their studies expect more practical exercises that represent both the applied character and the anticipated day-to-day career reality. The dominance of theoretical and abstract learning content in the basic course of study is viewed as a burden, and in part as an objectively unjustified form of screening out less suitable students. Respondents also complain of didactic inadequacies in the way knowledge is communicated.

The school is the central point for communicating information about technology, and particularly natural sciences.

2.1.0 CHILDHOOD TECHNOLOGY SOCIALISATION

Never before has there been such a great gap between the daily use of technology and the willingness of young people to choose a corresponding course of study. Use and interest have become decoupled, which is not particularly surprising on account of the extensive technologisation of day-to-day life and the economy. An age in which generations acquired technological understanding through successful, mechanical forms of play is drawing to a close. Although children can also experience technology directly in the virtual world, the link between technological learning, their own creating and experimenting and their understanding of technological interrelationships in the computer world is still underdeveloped. But the new virtual worlds also present an opportunity to promote technological understanding; particularly the creative use of the possibilities of digitization and computerization are acquiring a major role. The high significance of practical experience in all areas of socialisation at home, in school or at university can be viewed as a reconsideration of the manual/senses-based communication of technology via modern digital technology. It is already the case that a considerable proportion of young people tune and upgrade their computers and engage in play-based simulations.

2/2/0 TECHNOLOGY SOCIALISATION AT SCHOOL

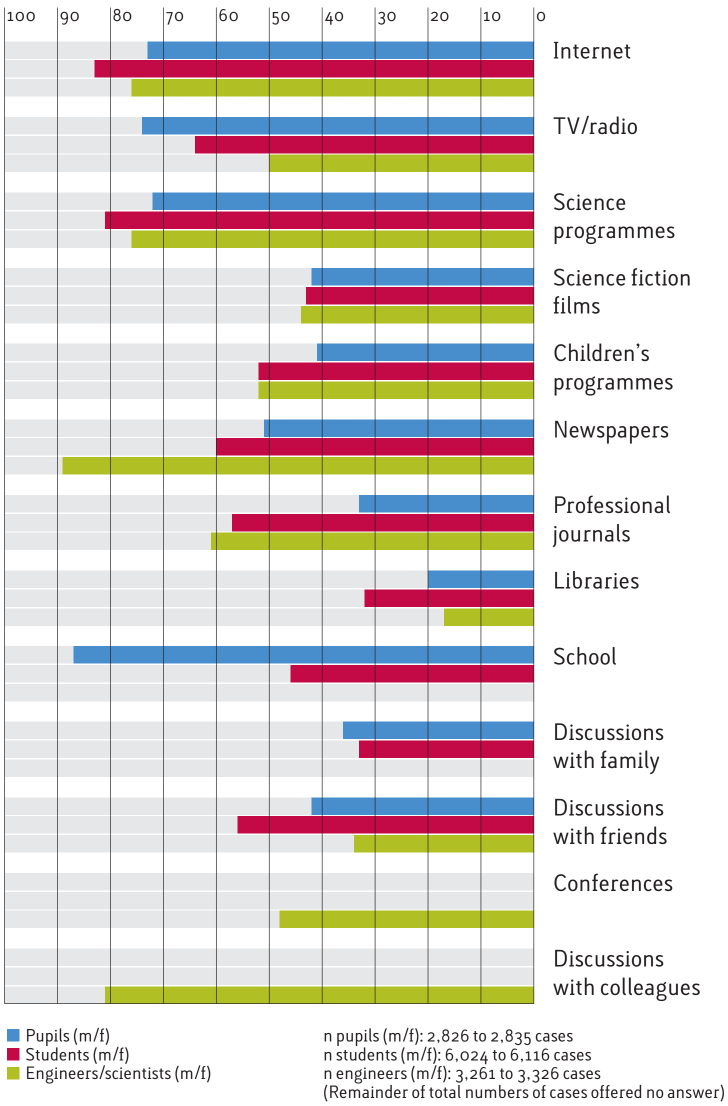
The school is the central point for communicating information about technology, and particularly natural sciences. Pupils identify the school as one of the most important sources of information in the area of mathematics, information technology, natural sciences and engineering, followed by mass media such as television (documentaries, science programmes) and the Internet. However, it is a long way from being informed to being interested. The dominant information media are evidently not succeeding in making technology attractive and interesting. One reason may be that too much attention is being accorded to the development of talents as a learning objective and too little to general interest in technology.

Consequently, the positive and negative social consequences and economic utility of technology should be communicated more intensively. To date, instruction has been concentrating too much on facts and on the relationship between natural sciences and technology. By contrast, the consequences of technology and innovation for the economy, society and culture remain underexposed. However, it is precisely these topics that can awaken interest and contribute to greater awareness of technical issues, particularly among girls.

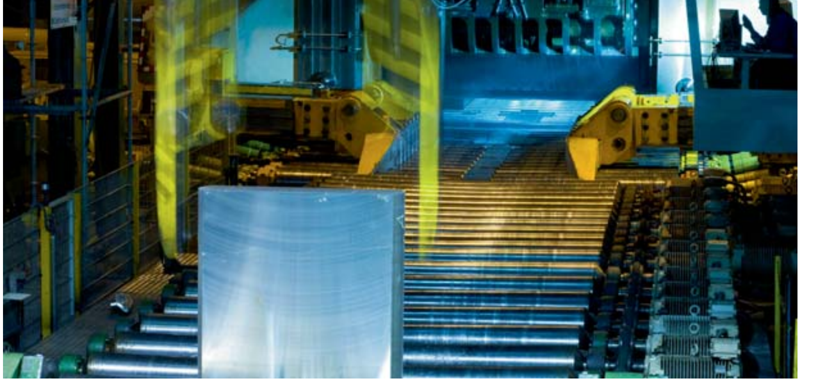
Figure 4

INFORMATION SOURCES AND MEDIA
FOR TECHNOLOGY AND NATURAL SCIENCES

“You obtain your information about technology and natural sciences through...”



Percentages // YEAR → 2009 // SOURCE → “Nachwuchsbarometer Technikwissenschaften”



The “Nachwuchsbarometer” confirms that pupils interested in technology do not necessarily need to be better than average. In political studies, English and particularly German, the marks of these pupils tend to be below average. In physics and mathematics or – if offered – in technology classes, these pupils generally perform better than the class average. In light of these findings, it could prove counterproductive for the career image of engineers that the media often portrays them as Germany's top performers. In fact, engineers are to be found both among the performance elite as well as at normal performance levels. They cover the entire spectrum of career and social positions. The specialist is joined by the generalist whose tasks include communicating technology directly with customers, for example in sales or service.

Communicating technology in schools can lay a permanent foundation for an abiding interest in technology. Without ongoing education, though (e.g. through methodologically and didactically high-quality technology instruction), the currently rather sporadic technology communication loses its effect. Because the promotion of technical abilities in the course of the educational system repeatedly “dries up”, phases occur in which interest declines or even disappears entirely. This trend must be counteracted through educational offerings both within and outside the schools.

In this context, individual actions and events are also important: they stimulate key experiences in pupils that provide important momentum for individual interest in technology.

From this, three important factors may be derived that increase the likelihood that young people will develop an interest in technology and discover their individual talents for a technical career: firstly, an early encounter with and playful exploration of technology; secondly, individual key moments in which technology is experienced as interesting and challenging (e.g. science centres, technology shows such as the "IdeenPark" (Ideas Park), hands-on laboratories and the like); and thirdly, continuous, didactically well-prepared technology education in schools. This can occur within the framework of a separate “technology” subject, but also in the context of related subjects such as proficiency training or physics.

Communicating technology in schools can lay a permanent foundation for an abiding interest in technology.

2/3/0

CHOICE OF STUDY AND CAREER

But an interest in technology and natural sciences by itself is not enough to prompt young people to take up a career in mathematics, information technology, natural sciences or engineering. The analyses of the "Nachwuchsbarometer" indicate that less than 50 percent of the existing potential pool of students with an interest in technology or natural sciences is utilized. The image of careers in the areas of mathematics, information technology, natural sciences and engineering is much better among young people than is generally assumed. However, the expectations of such a career show virtually no correspondence with the characteristics of the ideal career.

With respect to career counselling and orientation, pupils today depend more on their own impressions and experiences than on external information about careers. Internships, along with career information from the internet, are valued highly for gaining personal experience or obtaining specific information. Many pupils observe the labour market developments as reported in the media and to some extent orient their academic and career choices accordingly. Young people use this information as a basis for their own study choices particularly when extrinsic and intrinsic motives conflict. Overall, however, the perceived direct influence of social trends on the choice of study is rather slight. The effect is more latent and not on the immediate conscious level.

With respect to career counselling and orientation, pupils today depend more on their own impressions and experiences than on external information about careers.

Young people willing to study experience themselves as autonomous individuals. This has consequences, particularly for women. Female pupils do not regard a low proportion of women in a preferred course of study as a major obstacle to choosing that course. Thus, in this respect, the many initiatives to increase the motivation of girls and women have already had a positive impact. However, the actual experience of women students and engineers looks much different. Many have had negative experiences in their studies and career, and are subject to both individual and structural discrimination. This includes not least lower pay, but also a greater risk of unemployment and falling out of the workforce due to the inability to reconcile career and family.

Many students find that their expectations of the course of study differ greatly from their actual experiences, for example with respect to course content, didactic communication of the content and support from university staff. This produces a decline in motivation over the duration of their studies.

Analysis of the reasons for the choice of a course of study or career clearly reveals one thing: young people interested in technology or natural sciences are not a homogeneous mass, but instead break down into different groups for whom different motives apply, which must be considered concurrently and possibly promoted in a differentiated manner. The pool includes both confirmed technology enthusiasts as well as externally motivated rationalists for whom a secure job, high income and advancement opportunities are primarily relevant. The two motivations require different strategies for supporting and enhancing individual interest.

RECOMMENDATIONS

The results of the “Nachwuchsbarometer” underscore the fact that interest in technology must be stimulated and reinforced through differentiated educational activities in a much more targeted and broader manner than has been the case to date. To this end, new ways must be tried in order to respond appropriately to the great difference between the technology socialisation of the older and younger generations. For example, parents grew up with entirely different technical toys than their children. Technology must again become something that can be experienced directly so as to appropriately take into account the varied interests and motives of young people. Above all, interest in technology should be stimulated and maintained through sustained, didactically effective education of young people that is enriched with key experiences. This education must begin in early childhood and be pursued consistently throughout all phases of education.

Schools should not only promote technical talents and skills, but also provide general information about technology and its socioeconomic consequences for everyday living, life styles and the working world. This is also important, and indeed particularly important, for those young people who do not seek corresponding careers.

Some concrete recommendations for schools, career orientation, higher education, society (including media) and individual support can be derived from the results of the Barometer presented here.

Interest in technology should be stimulated and maintained through sustained, didactically effective education of young people that is enriched with key experiences.

4.1 SCHOOL SECTOR:

→ Technology education must be accorded much greater importance, either as a separate school subject or integrated within natural sciences instruction and proficiency training. In this technology-related instruction, hands-on experience and creative problem-solving should be given greater emphasis. At the same time, the application examples should be relevant to daily life and equally attractive for boys and girls. Above all, technology instruction should not be limited to explanations of function.

→ Technology as a separate subject would have four main advantages. Firstly, it could awaken, reinforce and expand interest in technology. Secondly, this instruction could be used to promote talented boys and girls early and in a targeted manner. Thirdly, instruction could contribute to a more realistic picture and more authentic image of technical jobs and their variety. And fourthly, technology instruction as general education could explore the connections to everyday life, the economy, society and politics and emphasize the relevance for our own culture and everyday experience.

→ Technology education can also be effectively integrated into natural-science and social studies instruction. The more interdisciplinary connections become apparent, the more attractive these subjects are for pupils. Physics can assume a special role here. Today, it plays the key role for access to technology and the choice of a technically oriented course of study. To utilize this opportunity, the lessons must be made exciting, relevant, interdisciplinary and gender-appropriate. Modern equipment and excellent subject-related and didactic training of teachers must also be ensured, as to date physics instruction in the schools has received predominantly poor assessments.

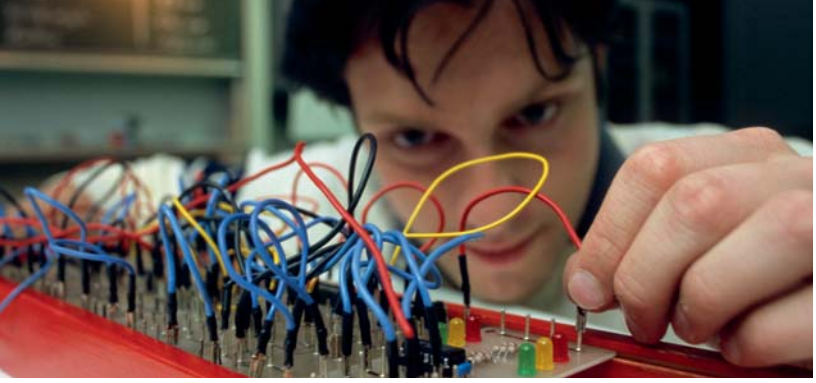
→ Technology education is a part of general education. It is a central component of the ability to fully participate in social and political life. The largest educational deficit is in the communication of technology in culture and everyday life. Thus, technology instruction must not be restricted solely to subject-specific lessons, but rather must include lesson units on the social consequences, opportunities and risks of technology. Interest in information about technology is extremely high, but interest in individual technologies is somewhat low. The function of individual technologies can be better explicated didactically via the technological impacts on the economy, politics, everyday life and work. The converse, by contrast, is seldom successful.

4.2 CAREER AND ACADEMIC ORIENTATION AND COUNSELLING

→ Pupils and students without doubt perceive and take note of social trends and developments when choosing their careers. However, they are not the central factors for their decision. When in doubt, the decision is made according to the young persons' own experiences or motives. As important as social trends are for a general technology climate, they are of little importance for specifically promoting young talent. Pupils should trust their own estimations of their talents, knowledge and qualifications more than short-lived labour market cycles or consistent prejudices regarding technological competence (among others).

→ The prototypical engineering profession no longer exists. Instead, the engineering profession is rightly perceived as a varied career field with primarily positive characteristics. The problem is thus not the image of the professional tasks of engineers, but primarily the image of the study of engineering. To this extent attention should be paid to a smoother transition from secondary to higher education. It is also important that pupils obtain a realistic picture of the requirements of study at the various institutes of higher learning. There is significant potential for improvement with regard to academic and career counselling.

→ One problem of the varied career image is the difficulty of assigning concrete tasks. From the perspective of the authors, this is the reason why internships have such great importance. Careers are defined through their tasks, and pupils and students possess rather vague to inaccurate ideas of what an engineer does. Consequently, pupils should be offered more career-related internships. One example that deserves mention in this context is the "Technikum", a BMBF initiative to promote academic and career orientation. Such measures can also match pupils' expectations horizon to the actual career practice.



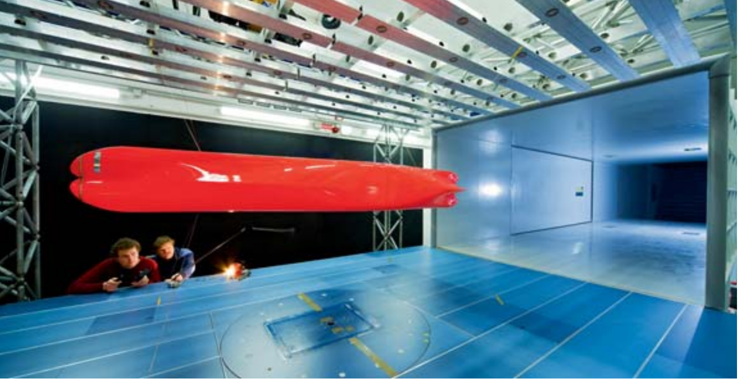
4.3.0 HIGHER-EDUCATION SECTOR

→ The image of the engineering disciplines as a difficult, laborious and complex course of study must not be used to justify communicating the subject matter in a dry, excessively abstract and scientifically theoretical manner. This approach inevitably disappoints the hopes of first-semester students for an interesting course of study. The majority of engineering students are not ranked among the performance elite of the schools. The institutes of higher learning therefore need to compensate performance deficits through targeted programmes (e.g. tutoring) to a greater extent than to date and place much more emphasis on practical applications, especially in bachelor courses.

→ In the academic reality, first-semester students are confronted with great pressure to perform as well as abstract, mathematics-heavy subject matter. This repels both intrinsically and extrinsically motivated students in equal measure. University-level didactics must be improved and modernized. Some institutes of higher learning have already successfully embarked along this path and have increased the attractiveness of their technical courses of study correspondingly.

→ Choosing a course of study entails a weighing of intrinsic and extrinsic motivational states. Some students wish to exercise their own abilities and knowledge and realize themselves, while for others a secure job is decisive, and still others are interested primarily in a high income and good opportunities for advancement. Over time, the proportion of students with intrinsic motivational states appears to increase. Thus, the choice of study becomes disjoined from the labour market, which could cause technological and natural-science careers to appear more attractive. Promoting both intrinsic and extrinsic-ideal motives is important because students can then better overcome their performance and motivation crises, which could reduce the rate of individuals who change their course of study or drop out. Promoting intrinsic motives begins with the expectations that upper-secondary graduates have of their chosen course of study: more practical application, more experiments, more teamwork and more project work. Didactic reform, practical application at the earliest possible point, better supervision and prompt comparison of the demands represent proven paths in the higher-education sector.

University-level didactics must be improved and modernized. Just some institutes of higher learning have already increased the attractiveness of their technical courses of study correspondingly.



4/4/0 SOCIAL INFLUENCES ON ACCESS TO TECHNOLOGY AND TECHNOLOGICAL UNDERSTANDING:

Media

→ Even where there is successful early technology education at home and in school, specific individual influences can impact interest in and openness toward technology both positively and negatively. Key experiences triggered by special events, but also by targeted media reporting, have a greater influence on technology interest than previously expected. To communicate the opportunities and risks, knowledge and interest, the existing Public Understanding of Science and Humanities (PUSH) concepts need to be developed further and extended to more target groups. The analyses of the Youth Barometer show these programmes to be motivational. However, they only have a sustained impact on technology interest when the schools "meet" the pupils with their motivation and curiosity and enable them to feed their initial interest.

→ The media are an important source of information. Young people are consciously aware of documentaries and general news on job market developments and trends. This also applies to the importance of technology for the economy, politics, society and culture. As this aspect is usually not dealt with in school, the importance of the media here is correspondingly greater. However, they often communicate isolated excepts that entail the risk of a misperception. The educational mission of the media is to present technology in its day-to-day significance and to explore the pros and cons as well as the opportunities and risks with respect to possible consequences. In this way, they can animate citizens to take part in decisions regarding the use, acceptance and consequences of technology.

→ Existing PUSH activities (such as those implemented in offerings of various museums and science centres) and the media presence of technical issues should be coordinated. Technically competent science journalism is one of the areas of action where technology and natural sciences can be better communicated to the general public. This field in particular is the scene of numerous positive activities, for example interestingly presented knowledge and documentary programming, whose effects have yet to be examined through evaluative studies. However, linking of this media presentation of technological issues to lessons and in everyday communication of young people is present only in a rudimentary form to date.

The educational mission of the media is to present technology in its day-to-day significance and to explore the pros and cons as well as the opportunities and risks with respect to possible consequences.

4/5/0 ENCOURAGING GIRLS AND WOMEN

- Female pupils should be encouraged individually early on so as to make engineering and natural science studies and careers in mathematics, information technology, natural sciences and engineering more attractive for this group. Currently, women and girls are structurally disadvantaged when it comes to promoting technical skills. Here, it is primarily up to business and the political sphere to make working conditions more attractive for young women and to compel the restructuring of organizational and working culture in terms of gender and diversity management. Programmes to promote equality of opportunity should exist not only on paper, but be implemented consistently from top to bottom.

- With respect to the choice of study and career, it is crucial that greater emphasis be placed on communicating the social contributions of technology. These are more important to girls than to boys in forming their interest in technology and in their choice of a course of study.

- Mentoring programmes in which women engineers accompany and support girls on their educational path are particularly recommended. Mentoring ensures a continuity, as well as promoting a role identity (role model function) with the mentor. Girls have a fragile technical self-conception because they tend to doubt themselves in spite of good qualifications, and because corresponding social prejudices reinforce these individual uncertainties. A gender-sensitive didactic approach, as well as lesson units in which the sexes are instructed separately at times (monoeducational approach), are important approaches in the school sector for counteracting the general trend toward technology abstention among girls and young women.

4/6/0 TECHNOLOGICAL UNDERSTANDING ON THE INDIVIDUAL LEVEL

- It is important to provide for greater discussion of how technology contributes to progress in the natural sciences (technical emancipation). The natural sciences have attained their positive image through their association with research and academic rigor. Technology remains too closely related to its economic functionality and too little to its scientific character and its contribution to social self-understanding.

- The systemic associations of technology (infrastructure, energy) are too much in the foreground, and are also communicated in a too one-sided manner. Pupils perceive opportunities and risks as normal consequences of technology and science. Most of them are ambivalent about technology Technology develops its positive aspects primarily in everyday applications. Consequently, these aspects that are taken so much for granted must be presented more intensively as a part of technology. The field of public discussion of technology must not revolve solely around problem technologies. The debates over the problems and risks of technology are important and useful, but technology-related communication must not be limited to this alone.

- Among young people, intrinsic motivational states are based on consumptive uses of technology, and thus give rise to positive affective technology associations. This could open the door to technology and to corresponding courses of study and careers. Intrinsic motives are also a good defence against performance and learning crises in a difficult academic discipline with high selection pressure. Consequently, what needs to be promoted are didactic access concepts that focus primarily on linking to everyday technology, exploring the relationship between functions and potential use and emphasizing the importance of everyday technology for the economy and society.

PROJECT PARTNERS

acatech – the GERMAN ACADEMY OF SCIENCE AND ENGINEERING

acatech represents the interests of German sciences and technology in Germany and abroad. As a working academy, acatech supports policy makers and society with technically qualified evaluations and far-sighted recommendations.

acatech works to promote sustained growth through innovation. acatech focuses on four core areas:

→ Scientific recommendations: acatech advises policy makers and the public on future technology issues based on the best of research.

→ Transfer of expertise: acatech provides a platform for exchange between the sciences and business.

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→ Voice for science and engineering: acatech represents the interests of scientists and engineers at a national and international level.

→ Further information is available at www.acatech.de

Association of German Engineers (VDI)

VDI is the largest engineering and scientific association in Germany. Founded in 1856, the Association is a domestic and international service provider and advocate for engineers and technology. It is a non-profit, economically and politically independent organization with around 136,500 members.

VDI maintains and cultivates a vibrant network on the regional, national and international levels. The regional structure of VDI comprises 45 Local Chapter and 15 Regional Chapter. The state VDI associations coordinate cooperation with the political and administrative instances of the individual German states. Internationally, VDI cooperates with numerous engineer associations so as to bring together the experience of engineers from around the world. On the EU level, VDI is represented in Brussels by its own office; the Association also maintains a capital office in Berlin.

VDI unites engineering and science. The heart of its engineering and scientific work are the VDI Technical Societies, in which over 10,000 volunteer members work in more than 800 committees to analyse the latest technical developments and make them available to the public, for example in the form of the VDI Guidelines, in Germany the recognised rules on the state of the art.

The VDI section “Career Profession and Society” explores the interrelationships between technological and social developments. This also includes education policy for schools and higher education. The VDI Knowledge Forum Centre for Advanced Training offers events covering all aspects of professional practice. The tasks of the two VDI Technology Centres of in Düsseldorf and – in association with VDE – Berlin are to promote future technologies and advise political decision-makers.

→ Further information is available at www.vdi.de

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