acatech TAKES A POSITION – No. 4

> STRATEGY FOR PROMOTING INTEREST IN SCIENCE AND ENGINEERING

RECOMMENDATIONS FOR THE PRESENT, RESEARCH NEEDS FOR THE FUTURE

acatech – Deutsche Akademie der Technikwissenschaften, 2009

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PARTICIPANTS AND PROJECT SCHEDULE

To examine the causes of the current dearth in young scientists and engineers and to analyse the opportunities for promotion in these fields, acatech convened an expert group of the following scientists:

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The experts compiled and analysed the major causes for the lack of young scientists and engineers in expert opinions covering the following five key areas: promotion of skills in children and adolescents, vocational training and studies, job market: appeal and image of technical and scientific occupations in Germany, Doing Gender in science and engineering, and technology and society. The expert opinions are the personal responsibility of each author and appear in a separate publication entitled "acatech diskutiert: Förderung des Nachwuchses in Technik und Naturwissenschaft – Beiträge zu den zentralen Handlungsfeldern" (2009).

acatech developed the following strategy for promoting interest in science and engineering on the basis of these expert opinions and further consultation with the expert group.

The acatech Executive Board syndicated the strategy for promoting interest in science and engineering on 19th February, 2009.

The recommendations for research activities and other measures to secure the necessary pool of professionals for the German scientific and innovation system were presented to the public during a "Nachwuchsgipfel" on 23rd March, 2009.

We would like to express our gratitude to the Federal Ministry of Education and Research for their financial support.

1 PREAMBLE

Germany is threatened by a dearth of professionals skilled in MINT occupations[1]. This can have far-reaching consequences for the innovative capacity of science and industry. Therefore it is the declared goal of acatech, the German Academy of Science and Engineering, to promote interest in science and engineering and to increase the number of graduates in all MINT fields.[2] acatech's proposed strategy for promoting interest in science and engineering focuses primarily on graduates in technical fields since the lack of professionals in this area is particularly pronounced and engineers play a key role in sustaining and increasing Germany's economic power.

In recent years, there have been numerous initiatives to promote young scientists and engineers. Nevertheless, they are insufficient to prevent the lack of engineering graduates. Although there was an increase in first-year students in 2007/2008 and 2008/2009, this positive development is not a true reversal of the trend since the absolute number continues to remain far below what is needed in a growth-oriented economy. acatech intends to help bundle existing activities under its "Platform for promoting young scientists and engineers" and to show perspectives for future developments.

The acatech strategy for promoting interest in science and engineering is directed toward policy makers, industry, schools and universities alike. The present global financial crisis has significantly changed social and, above all, economic conditions favourable to the successful promotion of young professionals. acatech earnestly appeals to industry to continue their existing activities promoting young scientists and engineers even in times of financial crisis. While diminishing or even discontinuing such activities would achieve short-term savings, this would discount the fact that a lack of skilled professionals would be even more critical during an economic rebound.

The acatech strategy describes research needs of the future and makes recommendations for action that can be taken in the present to promote young scientists and engineers in all phases of their development – from childhood to professional careers. The main elements of this strategy are briefly summarised in Chapter 2 and explained in detail in the subsequent chapters.

[1] Mathematics, computer science, the natural sciences and technology are known as the MINT fields.

[2] Since its inception, acatech has focused on the promotion of young scientists and engineers. It has attached special significance to the role of universities by making specific recommendations in this area. Among these are recommendations regarding the promotion of project work in engineering studies (2004-2005), the introduction of bachelor's and master's degree programmes in engineering (2004-2006) and the future of engineering promotion (2008). Projects that have recently been launched are MoMoTech – Monitoring of Motivation Concepts for Young Engineers (cooperative project of acatech, Universität Stuttgart and RWTH Aachen; current project 2007-2010) and the Studies Barometer for Scientists and Engineers (joint project of VDI – Association of German Engineers e.V. and acatech; current project 2007-2009).

2 SUMMARY

BASIC PRINCIPLES OF THE STRATEGY

acatech supports a systematic approach to promoting young scientists and engineers. This approach is characterised by:

- An interest and skills in science and technology should be stimulated in all stages of life – from childhood to professional careers. This should be viewed not in isolation but as an interrelated, cohesive whole.
- Initiatives and projects for promoting young scientists and engineers should be designed to run over an extended period and should be executed continuously to unfold their full potential.
- Promotional initiatives can only be successful if all players participate actively. Primarily these players include industry, schools, universities and policy makers.
- Measures for promotion must be accompanied by an evaluation.

INDIVIDUAL AREAS OF ACTIVITY

acatech has focused its strategy on eight areas of activity. The main recommendations for action in the individual activity areas are:

- Parental environment

  In many homes, technology and natural sciences do not have a (pedagogical) presence. The parental role in awakening their child's interest in technology and natural sciences and in developing initial skills in these areas is often underestimated.

  > acatech recommends

  Interactive experimentation kits, the use of student laboratories, visits to museums and science centres, and participation in pedagogical programmes offered by museums are as yet insufficiently tapped possibilities of introducing young people to technology.

  Kindergartens and schools should encourage parent involvement (such as in-class participation or sharing of career insights).

  Science television and web portals should expand programmes designed specifically for children and adolescents and make parents aware of their availability.
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- Kindergarten and preschool

  Age-based programmes in mathematics, technology and natural sciences are only gradually gaining ground at the primary level.

  A number of initiatives in preschools currently introduce engaging activities (such as chemistry experiments) in kindergarten but then run the risk of not using these to create a steadily growing basic understanding of science and technology.

  Opportunities available to kindergarten teachers to become qualified and trained in scientific subjects and didactic methods are often inadequate.

  > acatech recommends

  Even in kindergarten, playful contact with technology can be effortlessly employed to identify and promote interest and talent in the field.

  A precondition is to give teachers significantly improved opportunities to become qualified to teach these fields, such as courses at universities and continued professional development programmes for existing teachers.
- Primary and secondary school

  When compared internationally, pupils in Germany are often less competent in mathematics and natural sciences and are less interested in these fields than in other subjects.

  Technical content plays only a minor role in many schools and the time allotted to science lessons is often limited.

  Teacher training at universities is relegated to the shadows compared to other fields of study. Moreover, technology and technological sciences play only a secondary role in teacher education and continued professional development.

  > acatech recommends

  More technology-related subjects and issues should be anchored in the curriculum of science instruction at primary schools and in the natural science subjects of physics, biology and chemistry at the secondary level. It is also necessary to develop specific school books and instructional materials.

  The technical, didactic and pedagogical education and advancement of teaching staff needs to be improved. In general, education and continued professional development should impart to teachers the skills necessary to give technology and science lessons that focus on basic understanding and build on the capabilities and knowledge of students.[3]

  A significant contribution to fostering an interest in technology can also be made by extracurricular learning centres such as student laboratories and children's universities. These are particularly effective when they are linked with the content of the curriculum of a lesson and designed for a longer duration.

- University

  Now, as before, there is a low preference among students to choose engineering courses. Universities offer engineering programmes that are perceived as being too difficult, too analytical and too uncreative – and thus have limited appeal. Evidently too little is done at primary and secondary school levels to motivate pupils to pursue a technical direction. In addition, engineering occupations have the image of being outdated and unattractive. Outside influences relating to job market fluctuations also play a part in decisions against studying engineering. Women are still strongly underrepresented in engineering studies. Finally, the high drop-out rates in engineering and science studies deter students from choosing these fields.

  > acatech recommends

  To encourage students to enrol in engineering studies, these programmes must become more practically- and job-oriented by imparting job-related skills of a technical and non-technical nature and promoting interdisciplinary teamwork in projects and final theses.

  Additional capacities for engineering qualifications in Germany can be realised through greater formal (between vocational and tertiary education) and geographic (between education in Germany and abroad) networking.

  Student success rate can above all be increased by improving teaching of basic skills and knowledge. Courses are fill in the considerable academic gaps that students often exhibit are necessary. Greater support and performance feedback by instructors and better use of the options offered by project studies are further important aspects.

- Job market and professional world

  In Germany, most engineers are employed by industry. A career choice in engineering receives vital support from various information campaigns staged by industry. However, in view of the current financial and economic crisis, there is a danger that efforts by industry may slacken and secondary school graduates may decide against engineering studies despite good job market perspectives and career development opportunities.

  It is notable that many women with engineering degrees are not active in jobs in the MINT field. This primarily lies in poor opportunities to rejoin the job market (after a part-time job or parental leave) or for part-time work for mothers and fathers.

[3] acatech will make a separate and detailed statement on teacher education reform at a later time.

> acatech recommends

Company personnel management policies should provide training to technical staff in order to keep their qualifications current rather than pursue economy-related staffing and hiring practices. Constancy in hiring practices is particularly significant during an economic downturn to restore faith in job opportunities and promote student motivation.
Industry should offer graduates with engineering bachelor's degrees better perspectives on the job market and for lifelong learning, and enhance the possibility of obtaining a master's degree in work-study programmes later in their careers.
Methods for reconciling a career and family care should be improved. Good examples of successfully meshing engineering jobs, career opportunities and family care can encourage young women and men to pursue a degree in this subject.

– Promotion of and equal opportunities for women
Women are underrepresented in the technical sciences and the percentage of women is only slowly increasing. The number of women in MINT subjects and occupations decreases with every step on the educational and career ladder. Technology continues to be considered a male domain that is stereotypically associated with "male" skills.
While the diverse range of activities geared to promoting girls and women in technical subjects and studies has generally led to a rise in the number of female engineering students, now constituting around 1/5 of students, the figure is still too low – especially when compared internationally.
The portion of women engineers in the workforce (about 11 percent) also demonstrates that around half of female graduates do not pursue their learned occupation.

> acatech recommends

To motivate more women to choose a career path in engineering, positive signals are needed from the job market. Industry should actively expand the use of known instruments for promoting women, such as diversity management, self-commitment declarations, audits, etc., to achieve equal opportunity for women and men in employment, promotion and remuneration.

The reconcilability of engineering jobs, career opportunities and family care for women (and men) should be given considerably more attention by industry.

– Immigration of skilled professionals from abroad
Demographic development in Germany exacerbates the lack of skilled professionals and turns this into a lasting issue. International competition for the best minds confronts Germany with a major challenge.

> acatech recommends

As a centre for industry and research, Germany needs highly qualified immigrants and the international orientation they bring with them. It is important that immigration be steered toward qualified employees from abroad and toward qualified students, both first year and advanced.
Through a mentoring programme, for example, German-educated foreigners (foreigners who have been in Germany for a number of years and strive for, are obtaining or have completed an education here) should be more actively guided toward studies in engineering.

– Technology receptiveness and the image of technology
Technical sciences are considered to be difficult, abstract and incomprehensible. For most young people, grappling with technical subjects is not very appealing. The image of occupations associated with technology is fairly poor. Society's image of an engineer continues to be that of a highly-qualified, introverted tinkerer with limited social skills and poor teamwork capabilities.
Most technical and scientific occupations have great difficulty communicating technological issues to the public.

> acatech recommends

To eliminate the deficit of information regarding technical occupations and to effectively influence and change the public image of engineers, a long-term strategy needs to be developed by industry, science and policy makers to lend technology a new and improved public image and thereby implement it in a nation-wide marketing and communication concept.

3 INTRODUCTION

CURRENT SITUATION

Engineers4 form an occupational group that is vital for Germany's economic development and is a central link between new scientific discoveries and their application. In global competition, they are the technical innovators: products developed by engineers shape our lives at work, at home and in our free time. To maintain and increase Germany's economic strength, it is of central importance to secure the future of engineering in this country.

The approximately one million engineers in Germany constitute the largest academic group in the country. After an enormous growth period since 1997, the demand for qualified specialists and executives with an engineering background has stabilised at a very high level. In coming years, engineers will continue to one of the most sought-after occupational groups in the country.

The German industry has reported an increasing number of vacancies for technical specialists and executives that the job market has been unable to fill. Primarily those companies that are engaged in intensive research and development programmes and rely heavily on these professionals fear that the inability to obtain skilled professionals will lead to a weakening of their innovative and competitive strengths. This situation is expected to worsen in the future.

Universities compete with industry for highly qualified graduates. Industry often has the advantage of being able to offer higher salaries (which they can also distribute far more flexibly than, for example, public service). Thus, research and teaching are also faced with a lack of young scientists and engineers. For instance, the excellence initiative of the federal government and the states created 4,000 university scholarships for the promotion of science and research. Of these, despite new proactive and rapid recruitment paths, only 1,600 scholarships had been granted by the end of 2008. The lack of suitable candidates, the generally low, non-competitive salary level in the German science community and the competition with non-university research are given as reasons for the inability to find candidates for these scholarships.

In view of this critical situation for Germany industry, science and society, measures need to be taken to markedly increase the number of university graduates in engineering. The last education report of the OECD shows that current reform efforts are insufficient to prevent a dearth of professionals with a science and engineering background. This duplicates the findings of OECD reports over the last several years. This problem can be illustrated by analysing a few figures: Between 2000 and 2006, the number of university graduates in a specified age group increased from an average 28 to 37 percent for OECD countries. In the same period, the number of graduates from universities and universities of applied science in Germany only increased from 18 to 21 percent for the same age group. These differences are particularly pronounced in the engineering and other technical and scientific disciplines. In many OECD countries, 4.4 percent of degrees are awarded in engineering, while this compares to only 3.2 percent in Germany. As a result, in coming years it will not be possible to replace people leaving the job market with an adequate number of young scientists and engineers.

PROMOTION OF TECHNICAL INTEREST AND TECHNICAL SKILLS AT ALL LIFE STAGES

When deciding on a profession, a person's interests and skills play a primary role. The possibilities for promoting technical and science skills and interests must be viewed in relation to a person's development throughout his or her entire life. Skills and interests that are gained during specific stages of a person's life are important for the next stage of development. It is therefore imperative to take challenges and opportunities specific to every life stage into account when discerning the causes for the lack of skilled professionals and analysing how to implement a systematic promotion of young people into these fields.

The following measures are particularly important:

- A more aggressive promotion of technical and scientific interests in children and adolescents.
- Imparting (technical) skills and knowledge in early childhood. To successfully introduce all children and adolescents to mathematical and scientific subjects, programmes should be systematically initiated at the primary level or before. Subject areas should focus not only on reading and writing, but also on mathematics and science/technology. These basics should be enhanced by classes that build manual capabilities (arts & crafts and shop classes), media knowledge and computer skills. Exposure to the basic principles of nature should be an integral part of the preschool programme.

- A strengthening of cognitive prerequisites and motivations. At home, in kindergarten and at school, children and pupils should be encourages to discover their creative talent and to develop cognitive and design skills. In doing so, children incidentally learn how technology functions and about the building blocks of the physical world, an important factor in the promotion of technical, mathematical and scientific talents. Children and adolescents should be given more opportunities in class to demonstrate their technical talents. Depending on the type of school, this can be accomplished by highlighting technical adeptness (in art or shop class), problem solving capabilities (in interdisciplinary projects) or analytic skills (also in interdisciplinary projects).

SYSTEMATIC APPROACH TO THE PROMOTION OF YOUNG SCIENTISTS AND ENGINEERS

In this context and taking the policy reform debates regarding education into account, this strategy represents a systematic approach to the promotion of young scientists and engineers. The main elements of this systematic approach are:

- The existing but often isolated efforts should be combined to form a coordinated, highly visible and networked set of measures that enables the continuous support of children, adolescents and young adults throughout all life stages.
- The acquisition of skills should begin prior to school enrolment, continue throughout school with a mounting qualitative character and should also be advanced during a professional career. Creating, sustaining and expanding skills should be viewed as a lifelong process.
- The life stages from childhood to the professional world should be viewed not in isolation but as an interrelated, cohesive whole. Existing initiatives and projects for promoting young scientists and engineers often are not designed to have an impact over longer periods of a person's development. Models for the cumulative development of competencies, such as are worked out by schools in connection with educational standards, must be initiated at the preschool stage. The

fact that first-year university students frequently have inadequate knowledge in mathematical and scientific basics is a striking example of the lack of cooperation between schools and universities regarding educational and vocational goals.

- For the various initiatives and projects to attain their full potential, they require constancy and continuity. It is not sufficient to concentrate on science and technology for brief, isolated instances since this would not spur a long-term interest in technology in young people. Initiatives and projects should be arranged for the long-term to give pupils a better technical education and to awaken the desire for a technical career in talented children and adolescents.
- The promotion of young scientists and engineers cannot be borne by only one of the involved entities – be it schools, universities, industry or policy makers. The systematic approach is based on the assumption that the promotion of young scientists and engineers can only be successful if all involved players participate actively. Schools, universities, industry and policy makers should bear the responsibility together and, by making targeted efforts in this direction, better utilise existing potentials and create and realise new ones.
- Measures for promotion must be accompanied by defining parameters that makes it possible to evaluate their impact over the long-term. These include:
  - A clear definition of goals, i.e. of the effects that the measures are intended to produce,
  - A clear description of the instruments and methods used to bring about this goal,
  - A specific definition of the target groups,
  - A well-founded estimate of the period in which the desired effects are to be achieved, and
  - A definition of indicators that can be used to assess the success or failure of the measures.

THE acatech STRATEGY AND ITS AREAS OF ACTIVITY.

acatech's goal is to contribute to meeting the growing demand for engineers in Germany, ensure and continuously improve the high quality engineering education at German universities and to enhance the international competitiveness of Germany.

acatech presents the following strategy. The first step is to make recommendations for ways to promote a greater interest in technology and technological matters in general and a technical and scientific career selection in particular. These recommendations are based on the current state of knowledge and can take effect in the short or medium-term. acatech has identified eight central areas of activity. Five of these target areas are aimed directly at the involved players and three are cross-cutting areas that affect the aforementioned five areas.

The target areas:

- Home environment
- Kindergarten and preschool
- Primary and secondary school
- University and
- Job market and professional world

The two cross-cutting areas in which acatech sees good chances of further increasing the number of employees in science and technology are:

- Promotion of and equal opportunities for women and
- Immigration of skilled professionals from abroad.

The recommendations for action in the above-mentioned seven areas of activity will, however, have no impact if technology and the associated occupations do not acquire an overwhelmingly positive public image. Therefore, apart from the promotion of motivational factors for potential young scientists and engineers, it is also important to improve the general public's receptiveness to technology. Therefore, another cross-cutting area dealing with the

- Technology receptiveness and the image of technology is included with the other areas of activity.

In a second step, acatech identified knowledge gaps for each area of activity and on the basis of these derived research needs with the goal of further increasing the appeal and popularity of engineering studies.

4 AREAS OF ACTIVITY

4.1 AREAS OF ACTIVITY ALONG A PERSON'S LIFECYCLE

4.1.1 HOME ENVIRONMENT

In many homes, technology and natural sciences are not pedagogic topics. However, results from PISA 2006 underscore that parents play a vital role in helping children acquire knowledge in the natural sciences. Girls and boys achieve better competency in these subjects when their mother and/or father have an occupation that is technical or scientific in nature. It has long been known that academics, independent of their particular field, largely stem from families in which the parents themselves had an academic profession ("thesis of educational homogeneity").

From the perspective of achieving a cumulative development model, parental promotion of an interest in technology and science in early childhood is very valuable. Promotion here means to give children opportunities and encouragement to discover and explore environments associated with technology and the natural sciences. At an early stage of child development, teaching of technological information and skills should be interspersed along with motivational aspects and access to technology should be supported. Exposure can be in the form of playful contact with technology.

Parents and families exercise a particularly strong influence on the decision of young women to pursue a technically-oriented degree. In the family environment, girls are pointed toward technical or research-oriented activities less than boys. As a result, by the time they enter school, girls have less preliminary experience with technology than boys. On the other hand, we know that women with an affinity for technology were introduced to technical matters and explicitly encouraged to strive for a technical career primarily by their fathers. Also, girls whose mothers are educated in the natural sciences and work in this field more often enter into these careers than do other daughters. It can be concluded that fathers and mothers are important role models for their children and can provide essential support in the development of an interest in technology and science.

acatech appeals to parents, in their capacity as role models or conveyors of knowledge, to expose children to technological topics. This can be achieved in a number of ways:

- Parents can expose children and adolescents to technology and foster familiarity in very significant ways. Playful exposure to technology, the reading of technically-oriented novels, practical activities such as arts and crafts, woodworking and metalworking, and independent experimentation with science kits give children the opportunity to gain experience with technology. By supporting these activities, parents can promote continuous exposure to technology in their children's daily lives.
- Experiment kits for pupils are an excellent way of giving children and adolescents playful contact with the world of technology. They are still largely designed as learning tools in schools and only few are aimed at parents. The selection of generally available products of this type should be expanded.
- Parents can also obtain ideas from pupil laboratories found at many universities and businesses, many of which offer "introductory experimentation" with the goal of awakening a curiosity for science in young people and stimulating them to experiment, think and ask questions on their own. The introductory experiments can often be performed at home with only a limited amount of effort.
- Visits to museums and science centres, and participation in pedagogical offerings of museums are possibilities for introducing young people to technology that have not yet been sufficiently tapped.[4]
- Kindergartens and schools should increasingly approach parents with special technical skills to participate in various possibilities for including technology and science content in instruction.
- Collaboration with parents could be more intensively used to provide pupils with a close-up look at the working lives and careers of people involved in technology. In this more active manner, pupils can obtain concrete information on the wide variety of available professions in a lively manner.
- The many forms of scientific communications media, especially science television and web portals, should expand programmes designed for children and adolescents. Parents should be made aware that such programmes, tailored to specific age groups, are available to support their efforts.

4.1.2 KINDERGARTEN AND PRESCHOOL

At the primary level, pedagogical concepts primarily revolve around traditional fields such as social skills, motor skills, etc., as well as environmental and intercultural education. The subjects of mathematics, technology and natural sciences have only recently gained in significance. "Wissensfabrik"[5] ("Knowledge factory") and "Haus der kleinen Forscher"[6] ("House of the little researchers"), for example, were among the first projects aimed at expanding technical competency among preschool and kindergarten children, an approach that met with great resonance.

Last but not least, the quantitative expansion of kindergartens currently in progress should provide a good opportunity to reach more children with better educational offers and to introduce parallel measures that will improve the quality of education, care and support. Engaging girls and boys with technical and scientific subjects should be concretely embedded into the educational structure. Providing teachers with knowledge on the subject matter and didactic methods is a matter of urgency.

> Recommendations for action

acatech makes the following recommendations for action for the "Kindergarten and preschool" area of activity:

- Technical and scientific education in kindergartens should focus more strongly on the subjects of chemistry, physics, biology, technology and mathematics. These subjects should be introduced using methods based on experimentation and independent investigation, in guided projects and activities. They can be enriched through collaboration with businesses (from the optician to the carpenter) and public works (road and park maintenance, fire brigade or police).
- A daily encounter with technology and nature should be permanently anchored in the kindergarten curriculum and should extend to the subjects and fields named above and to general artistic and creative activities for the children. These latter experiences are an important, indirect contribution to the promotion of technical, mathematical or scientific talents.

[4] The "Zahllose Abenteuer! – Mit mathematischem Blick durch München" ("Innumerable adventures! – A mathematical excursion through Munich") project is an example of the integration of new learning venues, which can be visited alone or (even better) with parents (www.mathe-in-muenchen.de).
[5] See www.wissensfabrik-deutschland.de.
[6] See www.haus-der-kleinen-forscher.de.

- The daily routine in a kindergarten contains a multitude of activities that can readily be adapted to provide access to technology without much effort. These include repairs, garden design, meal preparation and pet care.
- Technical experimentation kits are an important learning tool for hands-on experience with technology. They are often made available to kindergartens by industry, which has launched various initiatives for this purpose. To achieve a long-term educational effect and to ensure the constancy of the offer, the provision of experimentation kits should be coupled with a continued professional development concept for the teachers.
- Parents should be encouraged to play an active part in their child's exposure to technology and science.. In the form of open collaboration, parents can actively contribute from what is often a wealth of technical experience, knowledge and capabilities to enrich the daily routine in kindergartens. For example, this might include field trips to businesses, which can give children a look behind the scenes.
- To design a preschool education that addresses the later stages of a child's life is still an unsolved challenge. While providing an introduction to technology and science in early childhood for children from three years until they start first grade is important, it should also have an impact on the primary school level through cooperation between kindergartens and primary schools. In addition, collaboration with parents should extend the reach of a child's learn experience in preschool and kindergarten to the child's environment at home.
- The technical and didactic qualification of pedagogical staff is a special challenge at the kindergarten level. Up to now, the education of teachers takes inadequate account of the contextual and didactic preconditions that must be met to promote kindergarten children in science and technology. These subjects should become a permanent feature of teacher education, especially in continued professional development. Universities, too, should offer opportunities for teacher education, continued professional development and advanced degrees. Such bachelor's study courses, which have already been set up at various universities of applied science, are trend-setting and should be expanded.
- Kindergartens should receive economic incentives or participate in competitive processes that direct more attention to technical content in kindergartens, encompass the qualification of teachers, and encourage kindergartens to actively engage in the testing of innovative approaches.
- Well meant, however, is not always well done. Often isolated initiatives are started that have no long-term impact. Therefore, it is necessary to systematically evaluate the introduction of new technical education concepts in kindergartens and preschool facilities. Even after the project phase is completed, continuous institutional support should be awarded to programmes that are given an excellent evaluation.
- At the kindergarten level, both boys and girls lack male figures such as mentors and role models in their lives. The number of male teachers in preschools and kindergartens is low. An information incentive should be launched by policy makers to motivate young men to enter careers in child care and early education and to make them aware of the various job opportunities available.

> Research needs

- acatech supports an intensification of kindergarten research in general. The promotion of children from non-academic social strata and the evaluation of learning instruments used in kindergartens to relate technical and scientific content are further areas that require research.
- While primary school research is a fixed and recognised part of German education research, kindergarten research is not included. Kindergartens and primary schools have separate educational mandates, which must also be taken into account in research. Although it is important and helpful to have models and programmes for the improved cooperation between kindergartens and primary schools, it is equally important for joint advancement to closely examine of the following questions: How do children learn in kindergartens and primary schools? How do children, families and the involved organisations experience the transition between the two levels? What bridges are built between these institutions in other countries, and what is their impact? What are the contours of the problem for which the cooperation between kindergartens and primary schools is the solution? Does this problem differ when considered from the perspective of children, families, pedagogues and organisations?
- The selection of an educational path in Germany is still strongly influenced by the social, cultural and ethnic background of the child or adolescent. Children and adolescents from immigrant families often have an interest in technology but if they select a technical occupation, they mostly choose jobs requiring vocational training and all too rarely take advantage of special advancement opportunities to embark on an engineering career. This "educational assimilation" could be countered by encouraging children from non-academic social strata at an early stage in their development. The prerequisites and possibilities to improve access to technology for children and adolescents from immigrant families should be researched more closely.

4.1.3 PRIMARY AND SECONDARY SCHOOL

In terms of the competency of adolescents in mathematics and the natural sciences, the findings of the international performance studies, TIMSS[7] and PISA[8], speak for themselves. They show that German pupils often exhibit inadequate skills in these areas. It is therefore not surprising that young people entering the job market or a university often lack basic mathematical, scientific and technical knowledge. In an international comparison, pupils in Germany are often less interested in mathematics, natural sciences and technology than in other subjects.

The amount of time dedicated to instruction in the natural sciences on any given school day continues to be on the low side and relaying technical content plays a minor role in many school types. To increase the enthusiasm children and adolescents display for technology and the natural sciences and to successfully introduce them to mathematical and scientific content, a foundation should be laid at the preschool level. At the latest this should take place at the primary school level and continue throughout the secondary school level. Natural sciences and technology should be taught continuously to build on early childhood interests and curiosity, to maintain these in later school years in students of all social strata, and to ensure that they play a role later when study/career decisions are made.

[7] For results and information on the "Third International Mathematics and Science Study" (TIMSS), see www.timss.mpg.de.
[8] For results and information on the "Programme for International Student Assessment" (PISA), see www.pisa.ipn.uni-kiel.de.

> Recommendations for action

acatech makes the following recommendations for action for the "School" area of activity:

- In the primary school level, the traditional "Science" class can in principle be a venue for relaying more technical content. However, this is often not yet sufficiently realised, despite an increased inclusion of these types of topics in the curriculum and lesson plans. Science class should contain a significant amount of technological instruction and these subjects should be more firmly integrated in the curriculum to ensure that the subsequent school levels can build on pupil knowledge and skills. The expanded technical content in science class is reflected in a new conceptual title for this field, "Humans, nature and technology".
- Science instruction at higher level schools should be expanded to include new topics. Their presentation should emphasise the importance of physics, chemistry and biology in our daily lives.[9] This will generate new learning areas that can incorporate technical topics and issues. To accomplish this, expanded lesson concepts and teacher and pupil materials should be developed at schools. Independent of scientific teaching and learning methods, it is also important to develop new didactic tools for teaching technological topics, customised for specific target groups. These technical didactics utilise modern, largely computer-based methods (simulation, audiovisual media, autodidactic learning software, Internet).
- Primarily at the beginning of the secondary level II (classes 7-9), pupils lack an inherent interest in abstract subject matters. This age group is therefore particularly suited for lessons linking technologies with the pupil's every day lives.
- Technical applications and questions are excellent starting points from which to present relevant and future-oriented contexts (traffic, for example) for discussion from different disciplinary perspectives (in addition to the sciences, other disciplines might be geography, mathematics and languages). In this way, technology becomes an integrative subject.
- High quality education at schools relies to a great extent on the education and advancement of the teaching staff in subject matter as well as pedagogical methodology. This is where the foundation is laid, with a current understanding of technology, for a future academic education in a technological field. A considerable range of options is available for the qualification of teachers, not only to enhance technical knowledge but also didactic, pedagogical and psychological expertise. In general, education and continued professional development should impart to teachers the skills necessary to teach technology and science lessons that focus on basic understanding and build on the capabilities and knowledge level of students.
  acatech considers high quality education of teachers to be an essential prerequisite for improving the quality of teaching methods and results at pedagogical institutions in Germany. The present teacher education system is structurally incapable of offering this to the necessary extent. Alternatives can be so-called Professional Schools of Education, such as that which is planned at the Technische Universität München and are being seriously discussed at several other German universities. acatech will make a separate and detailed statement on teacher education reform at a later time.
- A major factor in the advancement of teacher education and continued professional development is closer collaboration with the engineering discipline. The engineering discipline should take an active part in teacher education and continued professional development by making specific offerings.
- An important contribution to the promotion of interest in technology can be made at all-day school programmes. Systematic concepts with a technical and scientific focus that extend to afternoon programmes are hard to find. The pedagogical possibilities that exist here should be better utilised. A key role in high quality afternoon offerings should be played by cooperations with, for example, businesses, universities, and development and research laboratories. Good examples of industry-initiated programmes in schools are MINT-EC[10] and Miniphänomenta[11]. By utilising offerings at universities, pupils can receive hands-on experience in laboratories along with a working knowledge of methods and conceptual approaches applied in science and technology. Projects both in conjunction with external partners or not represent a special type of afternoon offering that focuses on practical technical issues which pupils can relate to their daily environment or that stem from "real" contractors. These can prepare pupils for the challenges of the professional and working world.
- Targeted measures should not, however, be limited to schools. A lasting interest in scientific topics can also be stimulated in children and adolescents through extra-curricular learning centres, which can supplement school education with meaningful and application-oriented content. Pupil laboratories[12] and lectures at universities for children ("Children's University")[13] are but a few examples. Unfortunately, the various available initiatives are often only scheduled for the short-term; they should be prolonged and made more beneficial to the daily lesson plan.
- Particularly in the context of the choices made by pupils regarding their courses in the upper levels of secondary school (Gymnasium), it would appear that measures designed to build the skills necessary to smooth the transition between school and university would be useful. Even today, universities organise bridge courses that are intended to ease a student's entry into university studies. However, these offerings should be intensified and expanded to meet the individual needs of students. The transition from school to university should be designed to avoid gaps in the curricula and syllabi and in didactic forms as students pass from one system to the next.

> Research needs

- The successful introduction of mathematical and scientific subjects to children and adolescents should systematically occur at the primary level at the latest, without neglecting the promotion of pupils at the secondary level. It is important to link instructional content between the elementary level and secondary level I. At present, curricular core elements including teacher and pupil materials are not available. In addition, teacher education does not offer adequate modules for technical and scientific instruction in these grades. There is a need for research to close this knowledge gap.
- Technology instruction that relates directly to the lives of adolescents requires examples from their daily lives that resonate equally with boys and girls. The traditional emphasis on typically male-oriented technologies such as vehicles, rockets and power plants should be supplemented by examples from other areas (such as the entertainment industry or textile technologies). Discovering age appropriate examples and how these examples can be used to illustrate the basic principles of technology requires more detailed research of didactics and pupil receptiveness.

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9 An example of this is the 'Chemie im Kontext' ('Chemistry in context') project; see www.chik.de.

10 www.mint-ec.de.
11 www.stiftung-niedersachsenmetall.de.
12 www.lernort-labor.de.
13 www.die-kinder-uni.de.

4.1.4 UNIVERSITY

Maintaining and expanding Germany's technological power requires a sufficient number of highly qualified graduates in engineering, a field that is particularly relevant to this context. Both at universities and at universities of applied science, the number of graduates cannot currently keep pace with the number of skilled professionals needed in the job market. The policy makers for educational, employment and economic policy in Germany are faced with the major challenge of dealing with the shortage of qualified university graduates in engineering, a situation that may yet worsen.

Students continue to shy away from study courses in engineering.[14] The reasons for this are many and varied:

- Technical degree programmes at universities and universities of applied sciences are considered by the public to be too difficult, too analytical and too uncreative – and thus have limited appeal – despite various reform efforts on the part of policy makers and universities.
- Evidently schools are unable to motivate an adequate number of pupils for technical courses. However, factors that influence the development of interests are not limited to academic ones. They also include the image of engineering professions themselves, which are considered to be old-fashioned and relatively unattractive, as well as external factors relating to job market fluctuations that likewise deter students from concentrating in engineering.
- Technology is largely perceived as a "male domain". Women are still strongly underrepresented in engineering studies.
- And finally, an above average number of young people drop out of engineering studies after they start.

Measures designed to counteract the shortage of engineers should be geared toward increasing the general willingness to study, encouraging students to pursue a degree in engineering and natural sciences, and improving study success rates.

> Recommendations for action

Universities have proven to be highly flexible, willing and capable in regard to instituting reforms. Taking this into consideration, acatech makes the following recommendations for action for the "University" area of activity:

- Success rates can above all be increased by improving the instruction of basic skills and knowledge. Important measures in this respect are:
  - Offerings that can offset the often considerable academic deficits that exist, even according to self-assessments.
  - A reversal of the principle that all difficult and largely abstract topics should be deliberated at the base level to allow more time for the interesting applications and in-depth topics during advanced studies. From the very beginning of studies, the motivation of students should be sustained by practically-oriented scenarios, without however neglecting the abstract requirements.
  - Greater support and performance feedback by instructors and
  - Better use of the options offered by project studies.
- A high level of correspondence between the interests and strengths of students and the degree requirements can significantly reduce the drop-out rate. Important requirements in this respect are:

  - That universities offer realistic information about degree requirements,
  - That universities select students carefully and assess their suitability in order to match them more closely with the profile of the respective university.
  - That mathematical skills of students be improved through better instruction. A prerequisite for this is achieving a high compliance between the requirements of university studies and the preparation received at schools.

- For engineering studies to become more appealing, it is essential that they be more practically oriented and more closely aligned to the professional world. Important measures in this respect are:

  - The increased teaching of job-related skills of a technical and interdisciplinary nature ("soft skills"),
  - The integration of non-technical subjects, especially with an intercultural background and
  - The promotion of interdisciplinary teamwork through innovative teaching formats such as project work and the creation of final theses jointly by multiple students.

- Women receive a variety of support services at universities, which should be continued and expanded:

  - The mentoring of female students will continue to play a major role. Through an intensive mentoring programme during their studies, female students can establish personal contacts with professors in their field. These contacts can be useful to obtain assistance in career-related decisions, such as the selection of an internship or a topic for the final thesis. A mentor's detailed feedback on her performance can improve a young woman's self-assessment and strengthen her self-image.
  - Arranging for female tutors for female students in the early semesters is likewise a common and proven practice and must be continued without interruption, especially to strengthen women's knowledge at the basic studies level.
  - By enhancing part-time study programmes and university child care facilities, family care can be better reconciled with studies.

- More flexible transfer possibilities between the various educational levels and areas, especially from the secondary vocational training level to the tertiary academic sector, could greatly contribute to increasing the number of engineering students.
- The potential of receiving engineering and science students from vocational schools should be tapped more effectively. Important measures in this respect are:

  - Better information given to potential students at vocational schools regarding the possibilities of obtaining a university degree within a limited period and at an affordable cost,
  - Easing of university acceptance requirements for potential students from commercial technical occupations who do not meet the traditional university entrance requirements,
  - Financial support and consultation specifically targeted at potential students from non-academic social strata, especially in terms of financing tuition,

[14] Detailed data on beginning students, advanced students and graduates in engineering can be found in the appendix.

- A broader offer of part-time and work-study programmes in the engineering,
- The creation of a clear definition, beyond curricular standards, of how skills acquired while working in a professional capacity can be credited toward university studies,
- The expansion of advancement scholarships for people with the necessary professional qualifications.

> Research needs

The following research is needed to achieve the objective of encouraging potential students to pursue engineering studies and then to effectuate a greater number of graduates in these fields:

- The type and structure of an engineering degree programme has a major influence not only on its appeal to potential students but also on the students' progress and ultimate success. There are a number of measures that can help improve the situation, such as more frequent use of university-specific selection processes, better consultation prior to a study course decision, more intensive support in the early semesters, better offerings to offset initial academic deficits, the introduction of more project-related instruction methods, dual studies, better forms of instruction, etc. The introduction of a staggered study structure and the modularisation of study has not as yet resulted in considerable negative effects in the shape of an increased drop-out rate or a greater number of students who change disciplines, especially at universities of applied science. This development is reinforced by the general lack of clarity about the benefits and status of (especially) engineering bachelor's degrees on the job market.
  This endeavour would involve a review of the spectrum of initiatives taken to restructure engineering studies as part of the general structural reforms of study. The aim is to analyse which forms of engineering studies are particularly innovative, which can lead to greater appeal of the engineering programmes and/or which can help reduce drop-out rates. For potential students, this would result in the identification of study course features that should play a major role in their decision making.
- Dual studies represent a contextual mesh of vocational and academic education. The degree of integration of theory and practice, and therefore the mesh of vocational and academic education, differs in the various study models. In view of the bottleneck situation in engineering, the question of how a further expansion of dual study courses could contribute to a solution deserves close examination.
- Numerous studies have been generated on the decision-making outcome of secondary level graduates who could potentially enrol in universities (gender, final grade at school, type of qualification for university entrance, type of school attended, certain interests, motives, etc.). In contrast, research deficits exist regarding the factors that influence a decision in favour of studies or vocational training. This applies even more so when looking at the specific branch of study selected. Of special interest is the interrelationship between the individual skill, motive and interest profiles of potential students and the specific features and requirements of the branch of study or vocational occupation. Firstly, because of the frequent occurrence of mismatches, it is primarily in this area that significant factors can be identified that lead to wrong decisions and disappointments among individuals, or that result in inefficiencies of the educational structure as a whole, which are particularly high in engineering. Secondly, the following questions should be investigated: To what extent do the capabilities and inclinations of potential students (still) match the specific features and requirements of an engineering degree programme? To what degree (if at all) do current features of the engineering degree programmes appeal to potential students with their personal profiles? Does this not lead to the loss of potential candidates for engineering degrees? Should the design of engineering studies be rethought? In terms of the promotion of young engineers and scientists and the development of appropriate implementation-oriented measures, it appears to be a promising approach to analyse the different skill and interest profiles of potential students and to align these with the profiles of the various branches of engineering studies.

4.1.5 JOB MARKET AND PROFESSIONAL WORLD

In Germany, most engineers and scientists are employed by industry. Companies create job profiles and define the credentials necessary for employment. Hiring policies have a significant influence on the job market situation and are instrumental in shaping career perspectives, which directly affect the occupational and academic choices made by young people. These are important factors when assessing the attractiveness of occupations and imply that industry and businesses carry a great deal of responsibility.

Industry, within the scope of its responsibility, should contribute to the promotion of young scientists and engineers to keep abreast of the rapid evolving economic and technical structural change. Various industry efforts such as "Think Ing", "Sachen machen" ("Making things"), "Wirtschaft und Schule" ("Industry and school") and "Bachelor welcome"[15] are important initiatives.

> Recommendations for action

acatech targets industry and businesses with the following recommendations for action:

- Engineering studies should be promoted by positive signals from the job market and occupational system. Especially in engineering, layoffs and lower levels of hiring have had a strong influence on study course decisions. Changes on the job market are registered by secondary school graduates and influence their study course choice. This influence on the availability of skilled professionals takes effect after a delay of several years, at which point it results in a shortage of workers. It is important to avoid the creation of so-called "pork cycles" – and one method is to instil a level of constancy in the personnel development and planning policies of companies. Company personnel management policies should provide continued education for their technical staff to keep their qualifications current rather than pursue economy-related staffing and hiring practices.
- In addition, industry should offer graduates with engineering bachelor's degrees better perspectives on the job market and for lifelong learning, and should enhance the possibility of obtaining a master's degree through work-study programmes later in their careers.
- Various information campaigns staged by industry for the promotion of technology in general and to improve the image and appeal of engineering occupations in particular should be set forth. They are an essential component in motivating pupils and students to choose fields relating to science and technology when entering the higher level of secondary school (gymnasiale Oberstufe) and universities. The number of initiatives is large. Better coordination between them could funnel their efforts more effectively to their respective target groups and improve their outcome.

[15] See www.think-ing.de, www.sachen-machen.org, www.wirtschaftundschule.de, www.stifterverband.org and www.arbeitgeber.de, and the comprehensive listings of the "MINT Zukunft schaffen" initiative (www.mintzukunft.de).

- Industry and schools should work together more closely. Joint efforts with businesses are key in creating high-quality all-day school programmes that contribute to promoting interest in technology. It is important to include an introduction to job opportunities in lessons and to supplement technology and science instruction with practically-oriented "field programmes" (visits to businesses, projects, integration of practitioners in lessons, etc.). Industry and schools both are challenged to build partnerships and cooperations.
- Career counselling in schools can be supported through the provision of information on career fields and perspectives and should be promoted and broadened in scope by industry career orientation initiatives.
- Industry should provide financial support directed at encouraging pupils to enrol in engineering degree programmes, such as a greater number of scholarships for female engineering students, the provision of student housing and the targeted support of foreign students, including supplying them with attractive general living conditions here in Germany.
- Industry already works closely with universities in many areas – from participation in internships to access in companies for writing of final theses. The cooperation between industry and science should be further expanded to increase the practical orientation of study courses.
- Industry should seek out opportunities for cooperation with schools and universities at earlier educational phases. It should expand its initiatives to include the secondary level I, since important decisions regarding the promotion of an interest and skills in technology are made at the beginning of secondary school. At universities, there is a deficit in the number of practically-oriented course offerings sponsored (in part) by industry – be it at the basic studies level of a "Diplom" programme or in an engineering bachelor's programme.
- Dual studies with an integrated vocational aspect have proven to be highly effective, linking vocational content with a university education at universities of applied science and vocational colleges. Such courses should be further expanded.

> Research needs

To further clarify the relationship between the job market and the appeal of technical and scientific occupations, the following studies would be useful:

- A study on the perspectives available to engineering graduates with a bachelor's degree on the job market and for lifelong learning. Good job prospects for graduates with a bachelor's degree are closely interrelated with gaining more students, especially from vocational schools. If a considerably higher number of foreign entry-level students in engineering successfully make it to graduation, several thousand more graduates would potentially be available to work as skilled professionals in Germany. Also of interest is whether bachelor's degree graduates actually take advantage of opportunities to further their qualifications after practicing their occupations for some time. One goal is to evaluate the effects of educational advancement and to trace how the individual qualifications change in the course of a person's professional biography.
- A study of new methods of personnel management for assuring the qualification of engineers and scientists, especially older skilled professionals, with a focus on company-sponsored continued education and its effects (lifelong learning). Quasi-experimental designs for existing innovative approaches as part of a change management are also conceivable.
- A study on the situation of commercial technical occupations in terms of applicant qualifications and future needs from the point of view of businesses. In addition, a selection of trained master craftsmen should be questioned on their career progression and their activities.

4.2 INTERRELATED AREAS OF ACTION

4.2.1 PROMOTION OF AND EQUAL OPPORTUNITIES FOR WOMEN

Technical occupations continue to be a male domain. Technology is considered to be a male territory that is stereotypically associated with "male" skills. Associated with this are (un)intentional gender-typical socialisation, culturally formed, gender-typical preconceptions of what is normal, and institutional policies such as hiring processes, income distribution and certain ideas about the reconcilability of job and family. These lead to real gender differences in technical experience, technical knowledge and technical interest. These differences, in turn, reinforce men and women in "Doing Gender" in their daily lives, perpetually reproducing the idea that "technology is a male domain".

While the diverse range of activities for promoting girls and women in technical subjects and studies[16] has generally led to a rise in the number of female engineering students, women still only comprise about 1/5 of students, a figure that is still too low – especially when compared internationally. The portion of women engineers in the workforce (about 11 percent) also demonstrates that around half of female graduates do not pursue their learned occupation.

The lack of women in engineering and technical occupations reinforces the stereotype with parents and pedagogues that girls and woman are less suited to technology and science than boys and men. The low number of female engineers also means a lack of role models, causing even those girls interested in technology and women trained in technical occupations to move in other directions or to turn away altogether" at the various transitions during their education and professional lives.

acatech sees a great need for action here to keep pace with the international trend and to utilise the potential of women in this field.

On the one hand, this requires measures designed to increase the general willingness to study, encourage students to pursue an engineering and science degree, and improve study success rates. These measures have already been presented in the "University" area of activity and apply to girls and boys, women and men, alike. Of special significance are enduring changes at the end of the education chain for women (as well as men) that keep those women who are already actively working as engineers or have been trained in this field in these occupations and promote them in their careers. These changes would directly result in positive effects for businesses and companies. This, in turn, would encourage female graduates to enter the job market as engineers and female students to complete their degree. In addition, it would be a motivator for girls (and their parents and partners) to consider engineering as an option and to embrace engineering studies. Finally, women engineers would be role models for female pupils taking courses with a focus on technology.

[16] See especially the "Nationaler Pakt für Frauen in MINT-Berufen" (www.komm-mach-mint.de). The goal of this package is to get policy makers, science, industry and associations to work together to accentuate the appeal of technical occupations and to motivate women to choose these occupations as a career.

> **Recommendations for action**

acatech makes the following recommendations for action for the "Promotion of and equal opportunities for women" area of activity:

- To motivate more women to follow a career path in engineering, positive signals are needed from the job market. In professional life, structural barriers have a major impact on women's success in technical and scientific occupations and on their continuation in these fields. The following measures would be imperative in eliminating these barriers:

  - The targeted employment of women begun under the label of Diversity Management of companies should be intensified and the existing training programmes and support plans designed specifically for women should be expanded. Greater emphasis should be placed on gender-sensitive selection procedures and equal opportunity recruitment processes.
  - Self-commitment declarations and audits can likewise lead to an increase in equal opportunity. To achieve this, however, businesses must rethink the largely informal recruiting policies and actively change those aspects of the male professional culture which prohibit an increase in the number of women working in engineering occupations.
  - Programmes for promoting family friendliness in businesses could support women and men alike as they enter a profession or when they re-enter after parental leave, thus helping to overcome disadvantages.

  - In addition, if the portion of women in technical occupations is really to be increased, binding commitments by businesses to practice proactive hiring and promotion strategies with respect to women are required.

- Mentoring and tutoring of women throughout their studies has proved to be an effective measure. Mentoring and tutoring should be continued beyond their studies for an extended period of time to prevent female graduates with technical or scientific degrees from changing direction to a career outside of science and technology after only a short time.
- The range of technical occupations women choose is limited and needs to be expanded:

  - A multitude of projects and offerings already exists that aim to provide girls and women with information to motivate them to pursue science and technology studies. Most of these address young women who are already interested. They now need to be broadened to include girls and young women who have not yet developed this interest.
  - According to findings on gender differences in relation to how young people decide on a profession, projects in this field should include creating more "living role models" to demonstrate to young women through contact with women in vocational training or at university that they, too, possess the necessary skills for an engineering career.
  - Most existing (occupational) pedagogical projects are directed solely at female participants. This has the consequence that the situation, hiring and behaviour of boys and young men remain untouched by these measures. The projects should also be open to male participants; they should be encouraged to take part.
- Recommendations for action have already been formulated in the "Primary and secondary school" area of activity. In addition, the following should be implemented:
  - Intervention offerings in schools should try to break down the gender association of technical and scientific subject areas and thus the male-oriented image of technology. The curriculum should address both boys and girls; separate instruction risks reinforcing and increasing the visibility of gender differences.
  - Interventions targeted toward the cultural dominance and behavioural characteristics of male pupils should be developed and implemented. The role and influence of boys in the creation of gender-typical behaviour and convictions of girls have largely been disregarded until now.

> **Research needs**

An important aspect of social scientific gender research regarding engineering occupations is its ability to also uncover differences between women. This question – an examination of differences between women rather than between women and men – has been given too little attention in research. acatech sees the following research needs:

- Regarding the mechanisms of discrimination against women in technical and scientific professions, there is a lack of organisational sociological research that, from the point of view of the engineering profession, looks at how professional cultures, which are generally considered to be male-oriented, vary among businesses, and that attempt to explain these differences. In order to bring about changes in businesses, these "hidden" structural barriers must be researched in business case studies and positive examples that break down these barriers must be named.
- Existing studies on gender inequality usually do not differentiate between different social and cultural groups of women (and men). A look at the cultural and social differences between women in terms of their origin, ethnicity and level of education reveals that common assumptions about what is "masculine" and what is "feminine" can vary greatly between different societies and regions, and even within a society. Gaining better insight into the variations among women can help uncover further obstacles for women in engineering.

4.2.2 IMMIGRATION OF SKILLED PROFESSIONALS FROM ABROAD

Demographic development in Germany exacerbates the shortage of skilled professionals and turns this into a lasting issue. An important and essential building block in solving this problem is the steering of worker immigration from abroad. Managed immigration of highly qualified workers is part of the innovation system and creates new jobs for other workers with a variety of qualifications. A substantial alleviation of the shortage of young scientists and engineers, particularly in subject areas in which an above-average number of foreign-educated professionals work, could therefore be achieved by simply introducing academically qualified foreign-educated immigrants in the system. Thus, Germany should strive to attract qualified entry-level students as well as advanced students. Because they received their education at a German university, chances are good that they will remain in Germany after completing their degree and integrate into the German job market.

> **Recommendations for action**

acatech makes the following recommendations for action for "Immigration of skilled professionals from abroad" area of activity:

- More than ever before, Germany must engage in international competition for the best minds. This includes the immigration of workers from abroad. As a centre for industry and research, Germany needs highly qualified immigrants and the international orientation that qualified immigrants bring with them.

– The likelihood that foreign students, German-educated foreigners and foreign-educated immigrants will embrace a concentration in engineering can be considerably improved by promoting a smooth transfer between education in Germany and abroad. The following measures are important:

  – The interest that foreign-educated immigrants show in German engineering degree programmes should be tapped more effectively and more support should be provided in order to raise the study success rates,
  – Regulations of the immigration law for academically qualified foreign-educated immigrants must be adjusted to eliminate the need for priority checking for academics who are not from the EU and to further reduce the minimum income limit that must be reached to be granted a residence permit.
  – The ability of the engineering field to help professionals climb the social ladder should be utilised more effectively with respect to German-educated immigrants,
  – The recognition of foreign degrees should be increased and accelerated, and
  – Immigration law should be redesigned into a qualification-based point system.

– Adolescents growing up in Germany within immigrant families enter universities less frequently than German adolescents. When they do enrol at universities, they are less likely to select technical subjects than their German counterparts. This is surprising because in most countries, immigrant families often climb the social ladder based on their technical qualifications. Therefore,

  – Children from immigrant families that exhibit special technical talent should be encouraged to take the step of attending a university. This applies even more urgently to girls.
  – Mentoring should be introduced for children from immigrant families. An ideal mentor would also stem from an immigrant family and thus be able to act as a role model.

4.2.3 RECEPTIVENESS TO TECHNOLOGY AND THE APPEAL OF AN ENGINEERING CAREER

Openness toward (modern) technology, a high level of attractiveness of technical degree programmes[17] and a positive image of the engineering profession are decisive factors for young people when deciding for or against technical or scientific studies.

Technology moulds today's society and is the ultimate means for achieving human goals. It shapes our everyday lives. However, the public treats technology as a commonplace consumer good and generally does not reflect on the reasons for how it functions. While technology is perceived and accepted as a means of simplifying our lives, the technical sciences are considered to be difficult, abstract and incomprehensible. For most young people, grappling with technical subjects is not very appealing. The long-term promotion of young engineers and scientists can only succeed if technology is associated with personal enthusiasm, with a passion for innovation, and if it is seen as enrichment our daily lives, for industry and for society. Without a doubt, technology is also linked with risks to the environment and to our social life. It is the task of engineers to design the technical world in such a way that potentially negative consequences are reduced and, where possible, eliminated.

[17] See the "University" area of activity.

acatech therefore considers it an urgent matter to sensitise the public to the social significance of technology and to underscore the central role that new technologies play in ensuring the competitiveness of the Germany industry.

Closely linked to the social image of technology is the perception of associated occupations. Pupils and adolescents have little knowledge of the job profiles of modern engineers. Society's image of an engineer continues to be that of a highly-qualified, introverted tinkerer with limited social skills and poor teamwork capabilities. This does not do justice to the everyday working lives of today's engineers. The engineering job profile has changed greatly in recent years; it now includes design tasks that relate not only to the technology itself but also to production processes and sales. This demands the ability to communicate well and to deal effectively with other people. In addition, engineers increasingly need to handle interdisciplinary tasks such as project management or the evaluation of economic and ecological issues. The public is rarely aware of these new demands. Deepening public awareness would help broaden the group of young people interested in an engineering degree programme to include those who see their talents and inclinations as lying beyond the classical technologies. In addition, engineers can often be found working as project managers or in management positions, and they frequently serve on the executive board of large companies.[18]

acatech intends to help increase awareness of the new image of engineering and to relay the modern character of this occupation. The goal must be to restore to engineering its former appeal by modernising the "engineering" brand.

> Recommendations for action

acatech makes the following recommendations for action for the "Receptiveness to technology and the appeal of an engineering career" area of activity.

– Technology is developed to realise the opportunities we see for its application. Science and industry are challenged along with policy makers to increase general knowledge about the possibilities and opportunities for technology and to promote public open-mindedness and a willingness for dialogue with regard to innovations.
– It should not be forgotten that technology also bears risks. Limiting these risks is a key task of technical researchers in cooperation with social and cultural scientists. Knowledge about the risks and benefits of technology and how to deal with them should be addressed both during engineering studies and in the course of continued education and further degree studies. This will help improve the quality of life for all of us through modern technology.
– Industry and society already support numerous projects and programmes that aim to improve how society responds to technology, and they should continue to do so even in times of financial crisis. Most of these effort are directed at members of society who are already interested in science and technology. They now need to be broadened to address people who have yet to develop this interest.
– Most technical and scientific occupations have great difficulty communicating technological issues to the public. Individual companies confront this problem by informing pupils early on about interesting job opportunities and task fields, and by introducing university students to the wide variety of professional development options open to engineers. Early on in

[18] Around 43 % of companies listed on the DAX are directed by engineers and scientists (Data: survey for this paper).

their development, pupils and students are given the opportunity to become familiar with the diverse working areas open to engineers through visits to companies, career weeks at schools, internships, degree dissertations and jobs as student assistants. These measures should be retained and expanded where possible.

- To eliminate the deficit of information regarding technical occupations and to effectively influence and change the public image of engineers, a long-term strategy needs to be developed by industry, science and policy makers to lend technology a new and improved public image and thereby implement it in a nation-wide marketing and communication concept.

- In Germany, there is a many formats for communicating scientific content, ranging from Year of Science programmes, which address the wider public, to individual events for special target groups such as kindergarten children.[19] These often isolated activities should be coordinated into a highly visible set of measures. A national coordinating centre should be established. This centre should collect information on available offers and make relevant data accessible. This would make it possible to efficiently develop new formats by drawing on learning effects and research results, thus ensuring that science communication will have a lasting impact.
- In this context, the promotion of "technical journalism" is an important goal.

> Research needs

In the last several decades, a technical transition has occurred that industry (professions) and society (educational system) have not sufficiently addressed in their technical communications, which are still shaped by the traditions of the 1960s and 1970s. acatech sees an urgent need for research investigating the activity fields of engineers and scientists. This research should analyse how the activity fields are changing and examine the image of this profession among young scientists and engineers, the media and the public. acatech therefore suggests performing the following studies:

- A study of the professional tasks and associated skills of practicing engineers and scientists, including a comparison with their original expectations. The investigation should be a cohort study that draws on a selection of young professionals and veterans to compare expectations and experience.
- An image study of beginning students, graduates and young professionals with the goal of analysing beliefs, attitudes and the information sources available to them regarding technical and scientific professions, education, and modern and traditional technologies. A cohort study should examine the stability and behavioural relevance of image components and identify determinants for possible change.
- As with the research objectives, which should be defined separately for the various target groups, the long-term evaluation of measures for improving receptiveness to technology should also be performed separately for each target group. Little research has been done to examine which measures increase the receptiveness to technology of those who do not already have such an interest.

The following questions regarding media coverage of technology and science and how technology and science are perceived should be researched:

- Of primary interest, but having received too little attention in research studies so far, is the role of media in shaping the images, perceptions and acceptance of technology. Based on examples of different technical occupations and new occupations, studies should be initiated to investigate how these occupations are presented in the media and which media enhance or diminish the status of (new and existing) technical occupations and to which degree.
- Increasingly, the mass media coverage of technical and scientific subjects is less a matter of scientific reporting than of the selling of popular topics in the guise of science. The role of online and interactive formats (series games, game software, wikis, fora) and how technology, technical professions and scientific disciplines are presented should be scrutinised.
- An important basis for a general understanding of technology is a knowledge of the visions of technology. Of interest is how their meanings, functions and potentials impact pupils and students as they select courses, choose a direction for study and decide for a particular career.

Regarding the communication of scientific information, research is needed to contrast the functions that the formats are expected to fulfil with those that they actually do fulfil. In other words, studies should examine which formats are effective in terms of public spheres they address and the goals they meet.

- Current formats of scientific communication are often not clearly focused. Different goals such as acceptance building, dialogue development and the recruitment of young people are often pursued in parallel. Therefore, it is necessary from the outset to explicitly state the effects that a format is designed to achieve. Long-term effects – mostly changes in knowledge, values and attitudes that influence career decisions – that transcend indicators that are directly measurable such as participant numbers, usually cannot be substantiated without this type of specification.
- The formats of scientific communication should be more firmly grounded in communications and/or pedagogical theory. This particularly applies to those formats that directly motivate young people to pursue technical or scientific studies. In order to design more effective programmes, it is important to intensify research efforts that analyse what motivates young people (especially girls) to choose a particular career and that examine developments as they transfer from school to university.

[19] For example, the 'IdeenPark' technology adventure world that targets adolescents, families and pupils (www.zukunft-technik-entdecken.de).

5 ADDRESSEES

The promotion of young scientists and engineers cannot be borne by only one of the involved entities – be it science, industry or policy makers. The primary tasks for securing the future of engineering are divided equally among them. These parties are the main addressees of the following recommendations for action. Only a joint effort will succeed in utilising and expanding the full potential of kindergartens, schools and universities and in strengthening the specific qualities of education at schools and universities in Germany.

acatech's recommendations for action are primarily directed at:

> Universities, industry and policy makers

- To develop a strategy for a new image in society of technology and the associated occupations
- To promote interest in technology along the entire educational chain, especially in women
- To provide more information on study courses and occupations

> Universities and policy makers

- To make Germany attractive again to excellent foreigners as a location to pursue their studies
- To strengthen teaching and improve the framework conditions for studies

> Universities and industry

- To expand cooperation regarding teaching and advanced education opportunities

> Universities and schools

- To improve the coordination of curricula and teaching objects

> Universities

- To expand teacher education and professional development programmes
- To create offerings for the primary level

> Schools and policy makers

- To ensure that technical content is anchored in the curriculum
- To adjust teacher education and advancement studies to the requirements of modern instruction of technical content
- To improve the technical equipment available at schools

> Schools and industry

- To intensify cooperation in the practical instruction of technical content

> Industry

- To practice a continuous hiring policy
- To attach more significance to gaining and advancing women engineers
- To sustain and expand special initiatives for the promotion of young scientists and engineers

> Policy makers

- To create favourable conditions that enhance Germany's appeal as a centre for study and research
- To expand university admittance and promote better transfer options between individual educational levels and areas
- To promote the immigration of skilled professionals, beginning students and advanced students

Last but not least, acatech believes it is important to underscore the major role that pupils, students and parents play in securing a pool of skilled professionals for the German science and innovation system.

Pupils should feel motivated to investigate and understand the technologies we use intensively on a daily basis. They should actively make use of elective course offerings available to them in technical subject areas.

Similarly, students are challenged to inform themselves about study course requirements before they commit to a certain direction of study, to approach their studies with the necessary dedication and concentration, and to resolutely apply themselves to completing their studies successfully.

Finally, parents have the important task of introducing their child to technology and of supporting their child's choice for a technically-oriented education and profession.

6 OUTLOOK

The Strategy for the Promotion of Young Scientists and Engineers developed by acatech, the German Academy of Science and Engineering, is an initial milestone in the battle against the shortage of skilled professionals in engineering fields. Additional milestones must follow. acatech therefore views its strategy as an impulse for further national discussion on strategic educational goals and on effective tools for their realisation. With the "Platform for the Promotion of Young Scientists and Engineers", acatech has created the conditions necessary for building a national network of players from politics, science and industry who, together with acatech, will participate in implementing and further developing the strategy. This network should highlight the significant role of technology in the German innovation system, coordinate the diverse activities for promoting young scientists and engineers, and together develop and realise further recommendations for action.

acatech invites science, industry and policy makers to use this platform to create new systematic approaches within the network. The promotion of young scientists and engineers should not be neglected, especially not during the current economic crisis. On the contrary, it is essential to maintain and expand existing initiatives, add new ones and concentrate and thus strengthen these activities. Especially under today's circumstances, we must focus on continuous measures to prevent a loss in the already tenuous technical and scientific talent that we so desperately need for an economic rebound.

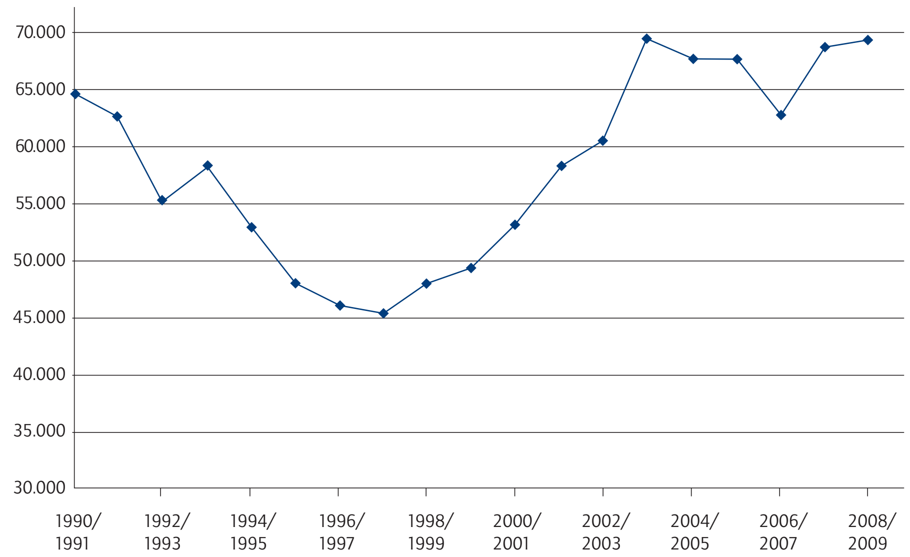
Only if we find convincing answers that work for all parties involved will Germany remain a centre of technology and innovation in the future.

7 APPENDIX: AT A GLANCE – IMPORTANT DATA ON YOUNG SCIENTISTS AND ENGINEERS 2009

For some time now, there has been a disconcerting trend in the area of science and engineering: Interest in technical and scientific occupations is waning in Germany. Neither positive developments on the job market nor targeted efforts by policy makers and industry have succeeded in perceptibly countering the lack of skilled professionals. The following figures illustrate the challenges we are facing.

- The existing lack of skilled professionals in Germany threatens to become exacerbated by demographic developments. In 2010, around 37,000 engineers will retire from the work force, and this figure will increase to around 43,000 by 2015. However, only around 40,000 young people graduate with engineering degrees every year – barely covering the number of engineers needed by industry to fill vacancies.
- The number of first-semester engineering students at universities exhibited a dramatic decline for several years (Figure 1). In the academic year of 1997/1998, the number of first-semester students was around 30 percent lower than in 1990 (approx. 45,100 compared to 64,800). This trend recovered in subsequent years. By 2003/2004, the number of first-semester students rose above the 1990 level for the first time (around 69,500). In 2004/2005, the figure again receded – along with the number of beginning students overall. This downtrend in first-semester engineering students continued until 2006. In 2007/2008, 68,400 students enrolled in engineering studies, an increase of around nine percent over the previous year. According to preliminary figures from the Federal Statistical Office from 1st December, 2008, just short of 69,000 students entered an engineering degree programme in 2008/2009.

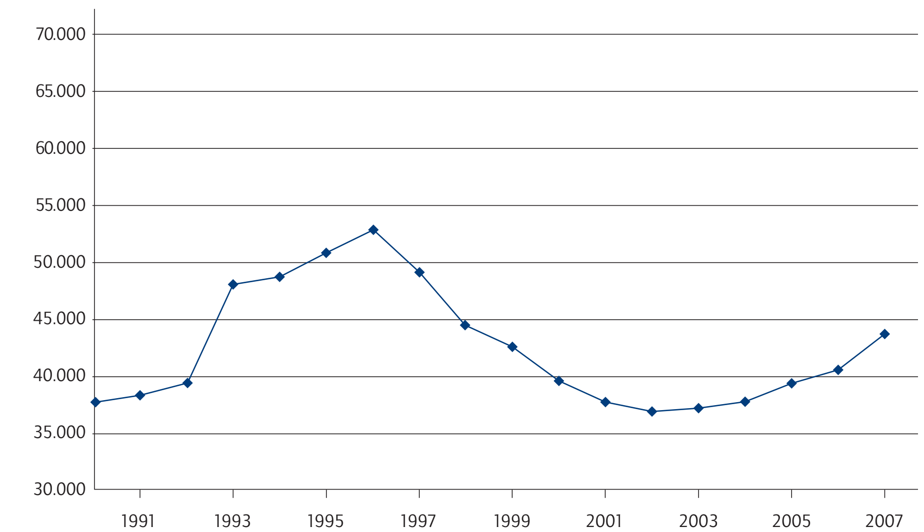
Figure 1: First-semester engineering students at German universities in 1990/1991 to 2008/2009



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.1

– After a temporary high in 1996, the number of engineering graduates dropped continuously and reached a low of 36,100 in 2002 (Figure 2). In 2003 and 2004, the number of graduates rose again slightly and then more significantly in 2005 and 2006. Despite another slight increase in 2007, the 2008 figure of 44,100 engineering graduates was still markedly below the 1996 level.

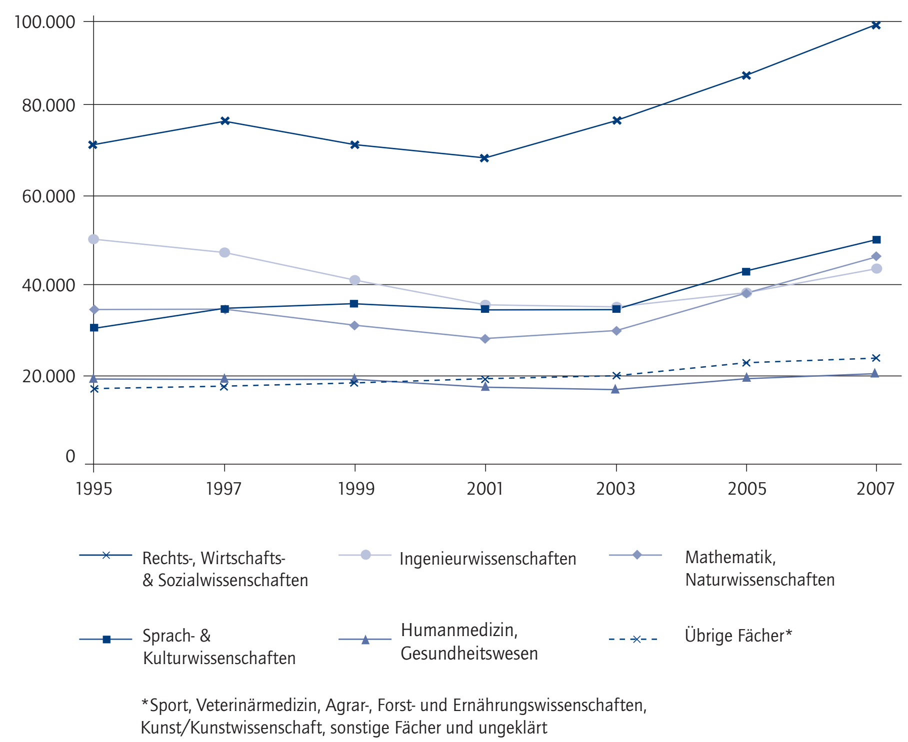
Figure 2: Engineering graduates from 1990-2007, including doctoral degrees



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.2

– Compared to other disciplines, the number of engineering graduates has dropped steadily. Gains have been experienced in law, business and the social sciences (Figure 3).

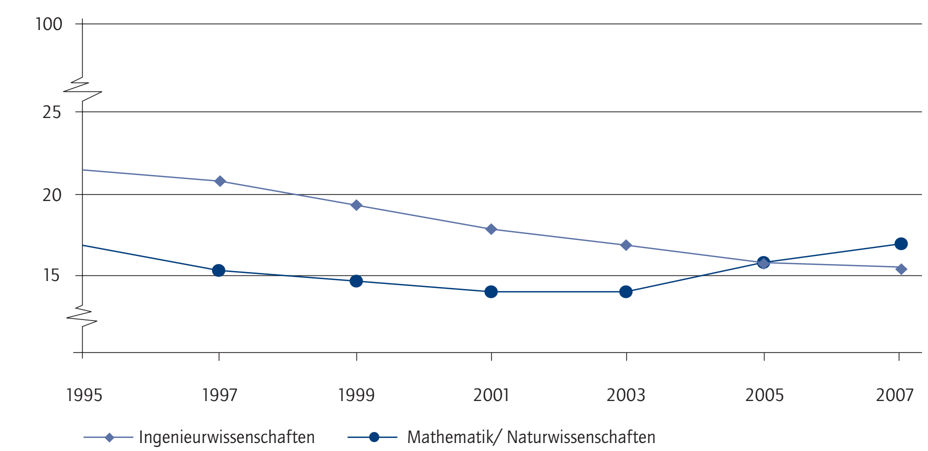
Figure 3: University graduates by discipline from 1995-2007



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.2

– The percentage of engineering graduates relative to the total number of graduates has dropped from around 20 percent in the mid 1990s to a current level of around 15 percent (Figure 4).

Figure 4: Percentage of science/engineering graduates out of total number of university graduates from 1995-2007



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.2

– The student drop-out rate (number of beginning students who cease studying without a degree and leave the university system) was 28 percent in 2004 and 25 percent in 2006 (Table 1). The drop-out rates in engineering programmes thus exceed the general average rate of all university degree programmes (between 22 percent and 25 percent since the early 1990s).

Table 1: Student drop-out and attrition rate and net attrition in engineering and computer science at universities (in percent) **– reference years: graduates from 2004 and 2006**

DISCIPLINE FIELD OF STUDY	ENGINEERING		COMPUTER SCIENCE	
Years Graduates	2006 (Beginning students 1999-2000)	2004 (Beginning students 1997-1999)	2006 (Beginning students 1999-2001)	2004 (Beginning students 1997-1999)
Drop-outs	25	28	32	39
+	+	+	+	+
Transfer to other discipline/field of study	17	17	13	19
=	=	=	=	=
Attrition	42	45	45	58
-	-	-	-	-
New students	5	10	6	8
=	=	=	=	=
Net attrition	37	35	39	50

Source: Heublein, U./Schmelzer, R./Sommer, D./Wank, J.: Die Entwicklung der Schwund- und Studienabbruchquoten an den deutschen Hochschulen. Statistische Berechnungen auf der Basis des Absolventenjahrgangs 2006, Hannover: HIS Hochschul-Informations-System, 2008.

– A similar situation can be seen at the universities of applied science (Table 2). At these institutions, the student drop-out rate of 26 percent in the engineering discipline is above the general average and is increasing over time.

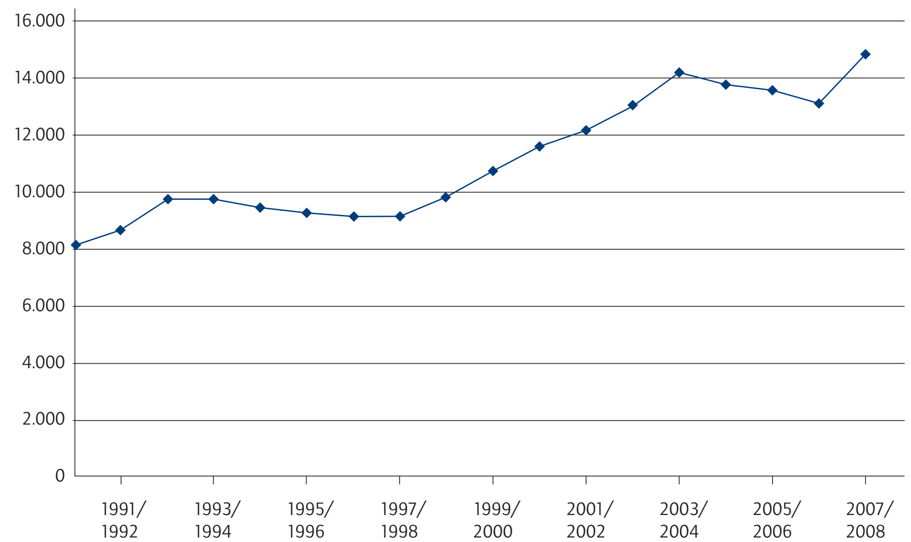
Table 2: Student drop-out and attrition rate and net attrition in engineering and computer science at universities of applied science (in percent) **– reference years: graduates from 2004 and 2006**

DISCIPLINE FIELD OF STUDY	ENGINEERING		COMPUTER SCIENCE	
Years Graduates	2006 (Beginning students 1999-2000)	2004 (Beginning students 1997-1999)	2006 (Beginning students 1999-2001)	2004 (Beginning students 1997-1999)
Drop-outs	26	21	25	29
+	+	+	+	+
Transfer to other discipline/field of study	4	6	4	6
=	=	=	=	=
Attrition	30	27	29	35
-	-	-	-	-
New students	7	8	10	24
=	=	=	=	=
Net attrition	23	19	19	11

Source: ibid.

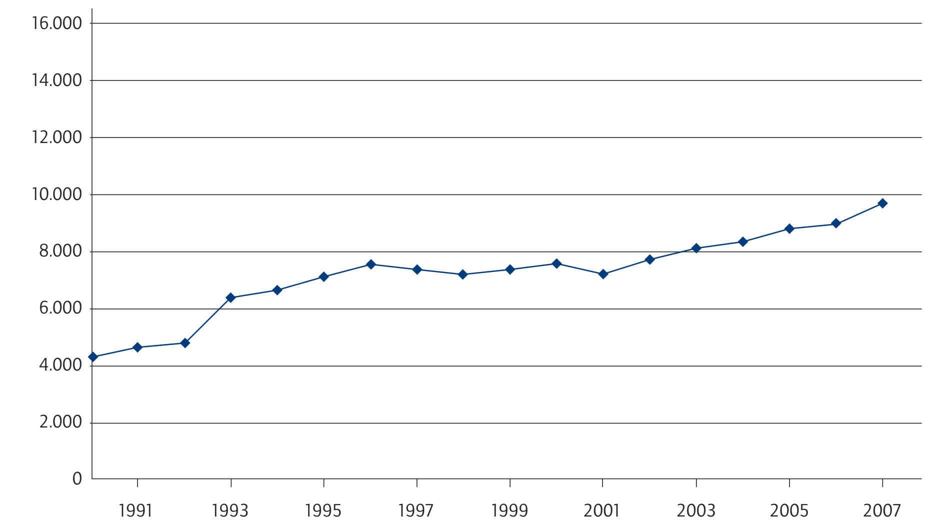
– The percentage of women among beginning engineering students (20.9 percent in 2007/2008) and engineering graduates (22.3 percent in 2007, see Figures 5 and 6) is still low.

Figure 5: Female engineering students beginning studies in 1990/1991 to 2007/2008



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.1

Figure 6: Female engineering graduates from 1990-2007, including doctoral degrees



Source: Statistisches Bundesamt, 2008, Fachserie 11, Reihe 4.2

> acatech – GERMAN ACADEMY OF SCIENCE AND ENGINEERING

acatech represents the interests of German science and technology within the country and abroad in a manner that is self-governed, independent and directed toward the common good. As a working academy, acatech supports policy makers and society with questions regarding a future in which science and technology plays a pivotal role. In addition, acatech's mission is to facilitate knowledge transfer between science and industry and to promote young scientists and engineers. The members of the academy include outstanding scientists from universities, research institutes and industry. acatech is financed by institutional funding from the federal government and the states, by donations and by project-related third-party sources. acatech conducts symposia, fora, podium discussions and workshops to promote technical advancement in Germany and to highlight the potential benefits of future-oriented technologies for industry and society. acatech addresses the general public with studies, recommendations and positions. acatech consists of three organs: The academy members form the General Assembly; the Senate, which advises the academy on strategic matters and provides an exchange between industry and other science organisations in Germany, consists of well-known personalities from industry, science and politics; the Executive Board, appointed by the academy members and the senate, steers the work of the academy. The main office of acatech is in Munich; it runs a capital city office in Berlin.

Additional information is available at www.acatech.de

> THE "acatech TAKES A POSITION" series

In the "acatech takes a position" series, the German Academy of Science and Engineering presents positions on current topics with a scientific, technological or technopolitical background. The publications contain recommendations for policy makers, industry and science. The positions are formulated by acatech members and other experts and then authorised and published by acatech.