Relation of Technology, Science, Self-Concept, Interest, and Gender

By Ingeborg Wender

The Need for Promotion of Women in Science and Technology

For nearly 20 years the topic of "women and technology" has played an important role in discussions about gender equality in Germany. The very first project for promoting females started in 1978 under the title "Women in Male Occupations." It was initiated by the Federal Ministry of Education and Science and was aimed at vocational-technical levels. Soon a variety of projects followed, financially supported by the Federal and District Commission for Educational Planning and Promotion of Research and by the individual governments of the various districts (Ostendorf, 1994).

The initial incentive to develop such projects was the fact that women were highly underrepresented in educational fields of technology and in those related to technology. Increasing the number of women in technology and science was a political goal. Consequently, many actions were initiated to increase women's participation in schools, universities, and/or extracurricular fields. Currently, special attention is being paid to specific subjects such as computer science and computer technology. The reason for this is the current lack of experts in these fields.

Despite the important role of technology in society, it is seldom taught in schools. That was not the case in the former Federal Republic of Germany. A special polytechnical teaching existed in schools; unfortunately, it was given up after the reunion. Therefore, we have an obvious deficit in Germany.

Because the proportion of students in natural, computer, and technological sciences has sunk dramatically in general, there are now various educational programs to increase the attractiveness of these subject areas. Most prominently, colleges and research institutions advertise intensively and offer their research resources to teachers and pupils. The best examples are the Göttinger Experimental Laboratory for young people (XLAB of the University of Göttingen), which concentrates on natural science, and the DLRSchoolLab of the German Center for Aeronautics and Space Travel in Göttingen, where aerodynamics is stressed. Almost all technical colleges offer pupils a day or a week of open house, including experiments and special projects. Pupils aged 15 to 20 are the main target group of these activities.

Because of the well-institutionalized promotion of women at colleges, a diverse science and technology campaign was developed, which has acted as a forerunner for current activities (such as our own projects Hands-On Technology [1993-1999] and Step In—Mentoring & Mobility [2001-2003], which will be described later). Computer science was and is generally an integral component in the projects. However, there is a difference between computer science as an independent subject and its application in a technical discipline. Concepts have been developed for both aspects. Activities for the promotion of women in Germany are currently somewhat one-sided with the emphasis on computer science.

Little Increase in Female Proportions in Technology and Science

In spite of these promotional efforts, the proportion of females in those "hard" courses in natural and computational sciences and in fields of technical studies and occupations remains small, though 45% of all students are female and 50% of the students in university beginning studies are female. Over the last decade the activities to encourage women have only slightly increased their percentages in the above-mentioned fields. The rate of female students increased in electrical engineering from 4.4% in 1992 to 8.6% in 2001, in mechanical engineering from 5.3% in 1992 to 10% in 2001, and in computer science from 13% in 1992 to 19% in 2001 (Federal Ministry of Education and Research, 1993–2002). The increase in women, even if small, may be explained by the efforts in the context of promotion activities for women, that is, the projects have been nevertheless successful.

Consequences

The above-mentioned increases in women's participation need to continue at a greater pace. This could happen if the projects could take long-term perspectives into account and not merely exist at brief intervals. Those who engage in promotional efforts, and all educators, for that matter, need to be aware of several other factors that may affect women's interest and participation in the technology fields.

Self-Concept (Self-Efficacy Belief), Gender, and Technology

Self-concept gained scientific attention for explaining the exclusion of women from technological fields, particularly young women's lack of confidence in their own efficacy to handle technical situations adequately.

The concept of self-efficacy (Bandura, 1997) has gained popularity in recent years, especially in educational and vocational issues. When choosing a career, perceived self-efficacy has long-term consequences. People with high self-efficacy expectations consider a wider spectrum of possibilities to develop themselves in relation to specific subjects and vocations and hold higher aspirations. For example, when choosing a career in mathematical/technical fields, high perceived self-efficacy bears more relevance than actual quantitative and technical competence (measured according to education and capabilities; Hackett & Betz, 1989). Subjective self-efficacy judgments are one of the most relevant determiners of success and persistence in a career.

Perceived self-efficacy refers to the beliefs in one's personal capabilities to organize and execute the courses of action required to manage prospective situations (Bandura, 1997). Self-efficacy produces effects in various ways, including mainly cognitive, motivational, affective, and selection processes.

People who have a low sense of efficacy in a given domain

- shy away from difficult tasks,
- have low aspirations and a weak commitment to goals,
- slacken their efforts and give up quickly in the face of difficulties, and
- diagnose insufficient performance as deficient aptitude and lose faith in their capabilities.

Self-efficacy beliefs are products of complex processes of self-persuasion. These processes rely on the cognitive "working up" of diverse efficacy information.

Bandura (1997) designated four sources of self-efficacy that can help to dispel doubts concerning one's own self-efficacy perceptions. These sources may enable persons to deal effectively with certain situations, each including

- mastery experiences, an enactive factor;
- vicarious experiences, influenced by perceived similarities to role models, observed;
- coping processes and participant and corrective modeling;
- encouragement from one's environment (e.g., social and/or verbal persuasion); and
- positive interpretations of one's physiological and emotional states.

Women generally judge themselves as being less efficacious then men for scientific occupations requiring quantitative skills, such as engineering and computing (typical male vocations where the percentage of women is equal or less than 25%), whereas men judge themselves less efficacious than women for education and psychology (typical female occupations where the percentage of men is equal or less than 25%; Wender, 1999).

Hackett (1995) provided empirical data that supports the theory that the low proportion of women in technical vocations can be traced back to women's low perceived self-efficacy regarding technical problem-solving skills.

Because gender groups experience socialization differently, girls and young women find it difficult to attain technical information and experience, and when they do, they cannot adequately process it. Women are hindered in building up and enlarging high self-efficacy expectancy for the technical and engineering fields. This is connected to a high degree of gender and social role model stereotyping.

A stereotype is a set of qualities ascribed to all members of a group of people or objects because of overgeneralization. Alfermann (1996) pointed out that women are perceived as preferring social relationships. For example, a woman is regarded and regards herself as preferring social relationships. Social roles are distinguished through behavioral expectations that society assigns as norms to members of a certain group. According to Alfermann, even today it is still usual that women take care of children and stay at home after the birth of a child and men do industrial work.

In accordance with the stereotype that describes women as incompetent in natural science and technology, girls often underestimate their own performance in mathematics and natural sciences. The TIMMS studies confirmed gender differences regarding confidence in one's own capabilities in these subjects and concluded that even very capable, highly successful female students tend to underestimate their own capabilities and assign success more to luck or accident (Baumert, Bos, & Lehmann, 1997).

Gender stereotypes and gender role expectations also influence expectations of different agents of socialization. Parents, teachers at schools and universities, and instructors in business develop expectations of their children, their students, and their trainees. Thus, a sort of self-fulfilling prophecy sets in and all involved base their behavior and experience on expectations set up by social groups. Even persons being educated follow these expectations, be they positive or—as concerning girls in relation to technology—negative for themselves.

The Function of Interests

According to Hannover (1998, in press), self-concepts are closely related to interests, and these, in turn, are closely related to vocational decisions. Self-concept influences the development of interests, and interests shape self-concept. Both determine the decision to pursue a subject or a vocation.

Todt and Schreiber (1998) defined interest as follows:

> Interests are domain-specific behavior—and experience activating and controlling motives, which are generalized, serving as structures of orientation and appearing in a specific manner as preferences for activities. Interests are essential elements of the structure of self-concept and are fully integrated in the individual's self-concept. (p. 25)

They also differentiated three forms of interest:

- General interests: content and age related, relatively enduring, whereby the influence by concrete experience is rather small, their function exists in orientation.
- Specific interests: relatively enduring, dependent on external hint and on positive experience, related to relatively specific contents or activities and to specific competence, their function exists in initiation activities.
- Active interests: positive emotional state, dependent on specific characteristics of situations, for example, success, positive social-emotional climate, can become dispositional if, for example, stabilized by positive consequences, their function exists in activating cognitive functions and stability activities.

As studies have shown, girls and boys, women and men have differing interests. Women prefer animated content, having something to do with people, having an obvious relationship to everyday life, relating to natural phenomena and of some use to humanity. Men, on the other hand, are less context dependent; they are more readily fascinated by apparatus and machines as such and concentrate on the object at hand (e.g., Häußler & Hoffmann, 1998). These elements can be distinguished as general interests; they are aligned with orientation and hardly available to change by experience. Since they are considered relatively stable, they must be taken into account in developing activities to promote an increased interest of women in technology and natural science.

In contrast, differing interests relating to individual subject areas such as German and physics can be affected by experience because they are specific interests. They can be influenced and affected by active interests. According to Todt and Schreiber's (1998) model, positive feedback, success, and a positive social-emotional climate closely associated with the various subject areas can influence them.

Hannover (1998) established that real life behavior experiences in the particular subject area are especially influential factors. Practical experience gives knowledge about content that is integrated into knowledge structures and anchors the corresponding interests as a personal experience and part of self-applied knowledge. These interests initiate new activities that contribute to the expansion of object-knowledge, of self-knowledge, and of the creation of self-concept. Thus, these components evolve into a circular process.

Hannover (1998) and Hannover and Kessels (2002) support the theory that in coeducational school situations, particularly with exercises that revolve around technology, gender segments of self-concept are activated and control interests in adolescents because of the presence of people of the opposite sex. In school situations where only women are present in a learning group, the gender-related segment becomes relatively inactive, and interests could develop independently. So if girls' interests should be turned to technology (against the gender stereotype), gender separate teaching is advisable.

These statements are empirically supported by the fact in 1980 young women studying technology or the natural sciences in Germany mainly graduated from girls' schools (Jahnke-Klein, 2001). And as Metz-Göckel (1999) stated, graduates from the women's colleges are very successful both in science and in the labor market.

Encouraging Women Into Technology and Science

Summarizing the preceding paragraphs, one may conclude that young women aged 15 to 20 are encouraged into technology and natural sciences if the following preconditions are taken into account.

- Regarding self-efficacy (Bandura, 1997):
  - Active, physical approach to technical problems.
  - Support from female role models.
  - An atmosphere that encourages confidence.
  - Help to interpret possible tension as positive stress.
- Regarding general aspects of interest (Häußler & Hoffmann, 1998):
  - Inclusion of technical problems in everyday situations or an everyday context.
  - Consideration of relationship with life, particularly with people.
  - References to natural phenomena.
  - Possibility to recognize human or social usefulness of the exercise.
- Regarding the aspect of specific and active interest (Todt & Schreiber, 1998):
  - Active examination of technology.
  - Acquisition of technical knowledge.
  - Creation of a positive social climate.

It should be stressed, though, that knowledge, self-concept (and in particular belief in self-efficacy), interests, and choices/decisions of vocation are closely related and mutually dependent.

In order for girls to avoid activating gender-related knowledge, a gender separate learning situation should be available (Hannover & Kessels, 2002). This would contribute to building up their perceived self-efficacy and promote development of a young woman's quantitative and technical talents. Future women engineers need to be provided with a learning environment that promotes and supports feminine general interests, giving them the opportunity to develop specific interests for natural science and technology to maximize their potential in these fields. Such schooling would induce girls and young women to gain technical knowledge, make them aware of their own competencies, give them a chance to develop specific interests beyond gender stereotypes, and give them the opportunity to acquire vocational skills in technology and natural science.

Projects of the Universities in Brunswick to Encourage Women

The projects of the universities in Brunswick, Hands-On Technology (1993-1999; Wender, Strohmeyer, & Quentmeier, 1997) and Step In—Mentoring & Mobility (2001-2003; Wender, Popoff, Peters, Müller, & Foetzki, 2002), are based on the social-cognitive modification strategies of Bandura (1997) as well as on the previously cited views of Hannover (in press), Häußler and Hoffmann (1998), and Todt and Schreiber (1998) in relation to interests. They combine activity-related measures (e.g., technology days or camps, computer workshops) with a mentoring program for schoolgirls, students, and experts from technology. The Step In—Mentoring & Mobility project concentrated its content on an interdisciplinary subject, that is, mobility/traffic with its technical, social, ecological, and psychological aspects.

The focus of the projects were on

- increasing knowledge of vocations in science and technology,
- increasing perceived self-efficacy of quantitative and technical tasks,
- increasing interest in technical fields, and
- considering occupational possibilities that include technical tasks as the dependent variables.

Several intervention modules were designed and applied. Established practices used in classes training students for their choice of future occupations were changed or complemented for the purposes of these projects: a three week-period of practical work, courses and vacation camps over several days designed for young women to develop interest in natural and technical sciences and computational science. In order to develop career orientation, a course lasting one week was offered to young women and men. The course included a work company over two days in business for the young women in technical domains and for the young men in social and educational domains.

In order to guarantee long-term promotion for the young women in the project Step In—Mentoring & Mobility, a particular mentoring program was conducted after the end of the vacation camp that offered special coaching for several months. During the camp the girls had the opportunity to write down their wishes for the mentoring program in a questionnaire.

Below follows an example of the practical studies offered yearly between 1993 and 1998 by the Hands-On Technology project . These three-week courses were attended by 120 young women (aged 15 to 20) in the above-mentioned period. The text is taken from an information brochure that advertised these practical studies in schools.

Institute of Flight Guidance and Control Technical University of Brunswick/ Germany

During their practical courses, trainees are involved in the preparation, the carrying out and the evaluation of simulation-and flight-experiments in a flight simulator. Different methods of approach and landing procedures, different turns and wind situations or specific motor flights are being tested and analyzed. These experiments aim at the test of new flight techniques in order to increase security standards in air traffic.

Moreover, trainees will get to know the evaluation of measured atmospheric data, such as pressure, density and temperature or data from real flight experiments such as position, velocity vector or air data. This includes an introduction to the measuring instruments of our plane at the research airport Braunschweig. Main aim of this survey at our institute are both the development and the test of new measuring techniques.

Instructor: Dipl. Ing. Ronald Blume

The main activity of the Step In—Mentoring & Mobility project is a mobility camp in the summer holidays that was executed in 2001 for the first time and will be repeated in 2003. More than 50 girls participated in the first camp. For one week, girls have the possibility to take an active role in technology by working on two projects each. During the mornings, projects are offered at different technological institutes. These projects mainly deal with actual research in the field of mobility. During the afternoons, the projects concentrate on practical, social, ecological, and psychological aspects of the topic.

Below follows an example of the practical project work offered by Step In—Mentoring & Mobility in the framework of the above-mentioned mobility camp. The text is taken from an information brochure that advertised the camp in schools.

Who likes shaking cars?

How to transfer driving test collected data on vehicle vibration to a hydraulic simulator for a survey on driving comfort

Institute of Vehicle Engineering, Technical University of Brunswick/Germany

The topic of driving comfort plays an important role in the development of cars as it is one of the main qualities in people's judgement of motor cars. Therefore, knowledge of human vibration-perception—how do people perceive and judge different vibrations—is of great importance for automotive industry.

By shifting the analysis of this vibration-perception from the road to a simulator, one not only reduces the amount of expensive driving tests, but also offers additional flexibility to the survey methods.

In this project, you are introduced to the

main tools and processes involved in the transfer of real vehicle movements to a test bench. You may independently equip a car with measuring technique and make measuring drives on the institute's grounds in order to collect data on the vehicle's vibrations. In the end, you transmit these to the institute's simulator.
Instructor: Dipl.-Ing. Thorsten Bitter

The above-mentioned activity-related measures not only offer the possibility to actively approach and experience technology, but, moreover, give the opportunity to form or renew mentoring relationships. Specific mentoring workshops also facilitate an interchange between schoolgirls, students, and experts from technology. These workshops train female experts for their role as mentors and role models, especially by showing their behavior in male-dominated contexts. They also give the opportunity to acquaint key qualifications.

The Step In—Mentoring & Mobility mentoring program was developed especially to consider the needs of schoolgirls. Temporally restricted forms of group mentoring as part of activity-related project measures are of great importance for the mentoring process. Individual contacts between a schoolgirl and several mentors often continue after the group measures are completed.

Evaluation

In order to guarantee a constant improvement of the intervention program, all parts of the projects are being regularly evaluated. Among other things, participating girls have to fill in pre- and post-participation questionnaires, concentrating on knowledge, self-efficacy belief, interests related to technical fields, and the choice of vocation, as well as the expectations and experiences from the different aspects of the project. Moreover, our own observations, audio and video recordings, and posters and reports made by the girls are part of the analysis. Participating tutors and mentors are also questioned in order to modify and constantly improve the programs.

Two examples of the evaluation are described here. The first example relates to the Hands-On Technology project, concentrating on the three-week period of practical work courses that were offered yearly between 1993 and 1998 and were attended by 120 young women (aged 15 to 20). The second example relates to the Step In—Mentoring & Mobility project and to its main offer, a summer camp, organized for the first time during the summer holidays in 2001. Fifty young women (aged 15 to 20) participated in this camp.

In the Hands-On Technology project the previously mentioned dependent variables were measured for the three focus fields (civil engineering, mechanical engineering, and electrical engineering) in pre- and post-participation questionnaires. The data were collected based on Betz and Hackett's (1981) measurement instrument. The statistical analysis compared the data collection for knowledge, self-efficacy, interests, and possible choice of vocation before and after the intervention of the intervention group (only women) with the control groups (women or men in three week-period of nontechnical practical studies). Follow-up analysis of the data was completed with the help of the Kruskal-Wallis one-way ANOVA (see Wender et al., 1997).

Between the intervention and control groups high significant differences were found with respect to the perceived self-efficacy related to the field of engineering; significant differences appeared with respect to knowledge and to interests; a numerical tendency was found with respect to possible choice of vocation. Most changes in the pre- and post-questionnaires were found in the intervention group.

As one result of Step In—Mentoring & Mobility, data were collected from young women participating in the summer camp. The questionnaires were based on the dependent variables previously mentioned, concentrating on vocations in the domain of traffic. Again, data were collected before and after the intervention.

The statistical analysis was done with the help of the Wilcoxon test. The data showed a significant increase after the intervention on all measured variables (see Wender et al., 2002).

Conclusion About Intervention

It is safe to conclude that the intervention programs were and still are successful. The questionnaires show significant changes regarding the schoolgirls' knowledge, their self-efficacy beliefs, and their interests in technology. Their newly gained and/or more consciously experienced knowledge and interests led to new perspectives concerning the girls' choices of vocations. They now consider more vocations, generally differing from stereotypically female ones. Their possible choices of vocation therefore significantly rose due to their participation in the project.

The mentoring workshops led to significant changes regarding the self-confidence of both schoolgirls and mentors in male-dominated conflict situations. Moreover, network-building can be noticed among all participating groups.

Therefore, when women are given the opportunity to engage in technical tasks and to succeed—and by doing so not to correspond to traditional gender stereotypes—they are contributing to the decline of the male stereotype traditionally connected with the perception of technology.

Ingeborg Wender is a professor in the Institute of Educational Psychology at the Technical University of Brunswick, Germany.

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