A 4 Digital education

Digital skills as a prerequisite for innovation and productivity growth

Digital technologies based on artificial intelligence, big data and cloud computing – and their associated disruptive business models – challenge Germany's previous specialization advantages (cf. chapter B 3). Examples of such business models include internet-based sharing and on-demand services like Netflix (video on demand), Spotify (music streaming) or Uber (driver-hiring service). In the course of this development, skills in software and algorithm development, or correspondingly qualified specialists, have become important prerequisites for productivity growth and innovation in both established and new industries.

Yet future demand for such specialists is only partially covered by the term IT professionals (cf. box A 4-1). One example is the occupational group of data scientists, which is rapidly establishing itself on the labour market; up to now, it has not been included in the official Classification of Occupations.[98] In the view of the Commission of Experts, therefore, a one-sided focus on IT professionals based on established definitions is not expedient in view of the developments of the internet economy.

The Commission of Experts has repeatedly urged an increase in the teaching of skills required to work with digital technologies – in short: digital education.[99] Key digital skills, i.e. all computer-, data- and IT-related skills (cf. box A 4-2), are an important basis for using digital technologies effectively. In addition, the ability to create software has meanwhile become a requirement in many professions. However, a focus on software alone is not sufficient – rather, interaction with other competences is necessary. In any case, the supply of qualified personnel needs to be increased through improved digital education

Box A 4-1

Definitions:
IT professionals and data scientists

An IT professional is an expert who practises a profession in IT. According to the Classification of Occupations (Klassifikation der Berufe, KldB)[100], the IT professions comprise all occupations in ‚computer science, information and communication technology'. These include the following professional groups:

- Computer science (among others: computer engineering, bioinformatics, and business, media and medical informatics); number of persons employed (2015): 192,200
- IT system analysis, IT application consulting and IT sales; number of persons employed (2015): 148,100
- IT network engineering, IT coordination, IT administration and IT organization; number of persons employed (2015): 144,500
- Software development and programming; number of persons employed (2015): 171,100[101]

Data scientists do not have a separate category in the KldB 2010. They generate information from large amounts of data and develop recommendations on ways to tap efficiency and innovation potential. The analytical tools and algorithms used are based on a fundamental knowledge of statistics and information technology, which must in turn be combined with domain-specific expertise in the respective areas of application.

Key digital skills

A binding definition of key digital skills does not exist. However, there is a useful definition in the ICILS (International Computer & Information Literacy Study)[102], an international comparative study of eighth-grade students. The study is based on the concept of technology-based problem-solving skills, as applied to adolescents and adults aged between 16 and 65 by the OECD's PIAAC study.[103] ICILS defines computer- and information-related skills on the basis of a functional literacy approach,[104] and describes the individual skills „that enable a person to use computers and new technologies to research, structure and communicate information, and to evaluate this information in order to successfully participate in life at home, at school, at work and in society".[105] Information-related skills are divided into two sections: Part I: Collecting and organizing information, and Part II: Generating and exchanging information.[106]

Part I: Collecting and organizing information
- Knowing how to use computers
- Accessing and evaluating information
- Processing and organizing information

Part II: Generating and exchanging information
- Converting information
- Generating information
- Communicating and exchanging information
- Using information safely

In the next survey in 2018, the ICILS will also survey skills in computational thinking as an additional option. Computational thinking is defined as a person's individual ability to identify and abstractly model a problem, dissect it into problem aspects or steps, draft and develop solution strategies, and describe them in a formalized way so that they can be understood and carried out by a human being or a computer.[107]

at schools and tertiary education institutions, in the dual vocational education system and in further training. Furthermore, digital education must enable students as early as possible to handle personal data responsibly.

High demand for skilled personnel for the digital transformation

There is a great demand for skilled personnel who can actively shape the digital transformation. The statistics on IT professionals in the narrower sense only allow a conservative estimate, since emerging professions such as data scientists have not been included in these statistics up to now. But even the figures on IT professionals in the narrower sense are unequivocal. According to a survey, 70 percent of German companies were already complaining of a growing shortage of IT professionals in late 2016. It stated that 51,000 posts for IT professionals were vacant, about 20 percent more than in the previous year and 35 percent more than the average for the previous nine years.[108] Furthermore, the number of advertised vacancies for IT professionals between August 2016 and August 2017 also rose by 20 percent.[109] According to an analysis conducted by an online job portal, one in three IT vacancies are advertised for longer than 60 days and are apparently difficult to fill.[110] The Federal Employment Agency (Bundesagentur für Arbeit) sees a shortage of skilled personnel especially in software development and IT application consulting.[111]

In a recent survey specifically among IT recruiters and HR managers from 200 companies in information and telecommunications technology, 41 percent of respondents indicated that they could not find enough candidates for vacant positions.[112] According to the survey results, the demand was especially high for web developers.

Digital education in German schools begins too late

The subject of computer science, if offered at all,[113] is not taught in Germany until the lower secondary education level. In addition, IT facilities, maintenance and internet access could be improved in many schools, despite a slightly positive trend in recent years.[114] Similarly, up to now there has been an insufficient focus on the didactical training of teachers with regard to the constantly changing content in the subject of computer science. Professional development of teachers in the use of digital media

in the classroom is below average by international comparison.[115]

By contrast, in the United Kingdom, for example, computing is already part of the curriculum in primary schools.[116] In 2014, it replaced ICT (Information & Communications Technology), which had been a compulsory subject for many years and focused primarily on teaching office applications (e.g. Microsoft Office applications such as Excel, Word, PowerPoint). The new subject in the UK is supported by economic actors like Google, which need technically trained young staff. Furthermore, the Royal Air Force funds programmable Lego robots, and the BBC distributes so-called micro:bit computers to schools with funding from Barclays Bank and Samsung. The UK has also promoted the use of cost-effective computer systems such as the Raspberry Pi, which can be used to make internet-capable computer systems for less than €30.[117] Educational materials for such systems are made available on open-access platforms.[118] Furthermore, competitions for pupils promote dissemination.

In Germany, on the other hand, there have hitherto only been hesitant and largely piecemeal efforts in this direction, primarily based on business initiatives. In the school subject Digital Studies, for example, primary school children learn how computers work using the ‚Calliope mini' micro-computer.[119] In February 2017, Saarland became the first German state where the Calliope mini is used across the board. Other Länder (Berlin, Mecklenburg-Western Pomerania and Lower Saxony) are equipping pilot schools with the devices. The Commission of Experts explicitly welcomes these efforts, but urges a significant increase in momentum. In addition, accompanying curricula must be quickly developed to help state ministries, teachers and learners.

Furthermore, micro-computers like the Calliope mini or the Raspberry Pi only represent one – albeit an important – part of the urgently necessary provision of IT equipment to schools, which also need powerful broadband internet access, special educational software, platforms and media, as well as a wide range of other internet-based services. A recent study[120] estimates that €2.8 billion per annum will be needed to provide adequate IT facilities in Germany's schools – which is likely to overburden Länder and municipal authorities. According to the study authors' estimates, even the five billion euros budgeted for the planned Digital Pact for Schools (DigitalPakt Schule)[121] (cf. p. 36) to develop digital infrastructures in schools and for the corresponding accompanying measures is far from sufficient. The Commission of Experts shares this view. It also points out that it is essential for the development of digital infrastructures in schools to go hand in hand with an increased commitment from teachers and more further training for teachers. Since the provision of qualified teachers via the regular system of teacher training or further training is very time-consuming, foreseeable bottlenecks among qualified teaching staff could be eased by recruiting more career changers.[122]

Programming skills are essential for IT training

The Commission of Experts has frequently praised Germany's dual system of vocational education and training. One of its most important advantages lies in the continuous adaptation of vocational content to technological change.[123] The Association of German Chambers of Industry and Commerce (Deutscher Industrie- und Handelskammertag, DIHK) last had the IT occupations[124] reviewed by the Federal Institute for Vocational Education and Training (Bundesinstitut für Berufsbildung, BIBB) in December 2016 to determine any need for modernization.[125] It suggested significantly expanding topics in the field of IT security (data security, availability, integrity and protection, including legal aspects) and incorporating more production-related content (e.g. robotics, sensor technology, 3D printing and virtualization) in the training syllabus. The BIBB also recommends reviewing and, if necessary, changing the IT occupational designations to make the profiles more attractive for female trainees.[126] New requirements in the fields of machine learning and artificial intelligence have not yet been taken up.

The fact that the content taught in vocational schools does not match operational requirements very well was regarded as potentially problematic. In a representative survey, only about 15 percent of trainees in IT occupations rated the vocational school content as good to very good in terms of how well it matched operational requirements.[127]

In the Commission of Experts' assessment, it is particularly important for both teachers and learners to develop programming and system skills at an early stage and in ways that are open to all technologies. Furthermore, further training – an area that is less well developed than initial training in Germany – is becoming more important.

In addition, a review is needed to determine which digital competences will be needed in all professions, not only in IT occupations, in the future. These skills must be integrated into the curricula as soon as possible. When drafting the curricula, it is particularly important to take into account the experience of companies that are technological leaders in the respective fields.[128]

Growing importance of computer science at tertiary education institutions

In the 2015/2016 academic year, almost 69,000 students enrolled in subjects relating to computer science (first-semester students, excluding teacher training).[129] This number corresponds to a 7 percent increase compared to the previous year. The percentage of women among the first-year students has been rising gradually, but continuously, since 2007. After 17 percent in 2007, it amounted to about 25 percent in 2015 – in the Commission of Experts' view a positive, but not yet sufficient development.[130] 51 percent of computer-science graduates took their examinations at universities of applied sciences, 49 percent at universities.

Apart from computer science itself, study subjects relating to computer science also include subjects that were introduced for the purpose of generating interaction between other disciplines with IT content. These subjects include, for example, business informatics, bioinformatics, computational engineering (often also referred to as computer engineering), as well as media informatics and medical informatics. About half of the graduates in the 2015/2016 academic year studied computer science without such a focus, almost a third specialized in business informatics. Media informatics came a distant third in terms of the number of graduates (making up 9 percent).

The relative importance of the subjects can be determined by dividing the number of first-year students in the respective subject by the number of all first-year students. The share of computer-science students rose from just under 2.9 percent in 2006 to 3.9 percent in 2016.[131] The share of business informatics also grew – from 1.4 to 2.1 percent.[132]

However, a general increase in the importance of IT content in other subjects cannot be extrapolated from the growing importance of study subjects relating to computer science. The Commission of Experts knows of examples of study subjects at German universities of excellence with no – not even subject-related – basic teaching in the use of software applications, databases or algorithm development. Unfortunately, there are no reliable statistics on this issue.

Examples of good practice can be found at the universities of Berkeley and Zurich. The University of California, Berkeley, offers students of all subjects a course in Foundations of Data Science, which is one of the prerequisites or compulsory courses in many departments. It familiarizes students with concepts of computer-aided calculation and statistics. No relevant prior knowledge is required for participation.[133] At the University of Zurich, the study courses in economics and computer science are being redesigned, so that they now leave room for a subsidiary subject. The range of subsidiary subjects comprises a selection of IT-related subjects for all non-computer-science students, such as computational sciences, data sciences and computer science for economists. Furthermore, a wide range of application-oriented subsidiary subjects are now available for computer-science students, e.g. in natural sciences and humanities.[134]

New further training opportunities in IT

In its 2015 report, the Commission of Experts drew attention to the increasing importance of further-training opportunities for a successful digital transformation.[135] Numerous public platforms – such as Coursera, Udacity, edX or iVersity – offer a constantly growing number of so-called MOOCs. Furthermore, microdegrees are increasingly being offered, which enable people to specifically update their knowledge; they build upon combinations of online courses and online examinations.

At the same time, private providers such as the US company Galvanize are increasingly specializing in establishing strongly application-oriented IT further-training courses – such as web development and data science – as quasi-standards in close consultation with both IT start-ups and established companies. The certificate courses, which take just a few weeks to complete, meet the economy's growing demand for continuous further training of employees in the latest digital skills. The course contents are continually being adapted to needs, and in many cases are directly based on companies' specific problems. In addition,

special strategy courses on the value-creation potential of digitalization address the management level.

The Commission of Experts expressly welcomes new providers and forms of further training, especially since the need for further-training courses in IT seems to exceed supply. A survey among HR managers notes a marked discrepancy between the digital skills which respondents consider important to extremely important and current training opportunities.[136] German tertiary education institutions have not been particularly active in this segment to date.

Very few computer specialists in leadership positions

In large German companies, there are hardly any computer specialists in executive positions. According to a recent survey conducted by the Commission of Experts, in 100 German prime standard companies[137] with a total of 448 management board members, only 23 of the directors (5.1 percent) had completed a study programme or apprenticeship training in IT. Only one in five companies have any directors with an IT background at all.[138] In view of these figures, there are concerns that the digital transformation is still too rarely given top priority in German businesses. The question also arises of whether the required expertise is available at management levels in public institutions and administrations.

Federal measures in digital education could be expanded

Against the background of the problems in digital education mentioned above, the following section describes the measures taken by the Federal Government to overcome these deficits.[139]

From 2016 to 2019, in its umbrella initiative on vocational training (Berufsbildung 4.0), the BMBF is funding, among other things, inter-company vocational training facilities (IVTFs) and centres of competence by procuring digital equipment and drawing up new training concepts. The purpose of IVTFs is to complement training in companies and vocational schools by providing practical courses in digital skills.[140] The BMBF has budgeted approximately €84 million for this measure. In addition, a funding programme called ‚Digital Media in Vocational Education and Training' aims to support projects that try out new teaching and learning formats for media-based qualifications and to develop workable solutions for learning with digital media in an occupational context.[141] This includes, for example, learning with the help of mobile technologies such as smartphones or tablets, and improving the media skills of trainees and the training staff. Approximately €152 million, including co-financing from the European Social Fund (ESF), has been budgeted between 2012 and 2019.[142]

Further measures within the Berufsbildung 4.0 umbrella initiative include JOBSTARTER plus, which aims to support SMEs in continuing to develop their further training,[143] as well as a project called ‚Skilled labour qualifications and competencies for the digitalized workplace of tomorrow', which examines quantitative and qualitative effects of digitalization on qualification requirements.[144]

The Digital Pact for Schools proposed – but not yet implemented – by the BMBF plans to supply all schools (primary, secondary and vocational schools) with broadband connections and WLAN coverage, and to install internal data infrastructures and servers within the next five years.[145]

The School Cloud project, which is run in cooperation with the Hasso Plattner Institute and the ‚Excellence network of schools specializing in mathematics and the natural sciences' (Nationales Excellence-Netzwerk von Schulen mit Sekundarstufe II und ausgeprägtem Profil in Mathematik, Informatik, Naturwissenschaften und Technik, MINT-EC), aims to provide students and teachers with easy access to learning and teaching material.[146] To promote pupils' interest in computer science, the BMBF also launched the Youth Computer Science Competition in May 2017.[147]

The Commission of Experts welcomes the initiatives launched to date. The Digital Pact for Schools must urgently be given a sufficient funding framework and become a fixed part of the new Federal Government's programme.

Recommendations

The Commission of Experts welcomes the fact that the Federal Government expressly recognizes key digital skills as a qualification requirement in an increasingly digital world.[148] However, it still sees

a considerable need for action and recommends the following measures by the Federal Government and the Länder to expand digital education:

- Key digital skills should already be taught in primary schools nationwide. Teachers in schools need not only excellent IT facilities, but also ongoing further training in order to lay the foundations for the digital knowledge-based society. The Digital Pact for Schools must therefore urgently be given a sufficient funding framework and become a fixed part of the new Federal Government‘s programme. In order to mitigate the foreseeable shortage of qualified teaching staff and accelerate development, the recruitment of career changers should be expedited. The provision of qualified teaching staff via the regular system of teacher education alone would take too long.
- In the dual system of vocational education and training, the range of courses offered in IT, especially in programming, as well as software and web development, should be significantly expanded across all occupations. In addition, IT skills should become a fixed part of all vocational training programmes.
- Tertiary education institutions should teach programming skills and knowledge of software and web development, as well as data sciences and methods of machine learning – also across all disciplines. In this context, the new possibilities offered by Article 91b of the Basic Law should be used in a joint effort by the Federal and Länder governments to implement suitable best-practice approaches in tertiary education institutions.
- Against the background of rapidly changing qualification requirements in IT, it is essential to expand the possibilities for further education (lifelong learning). In the Commission of Experts‘ view, novel training opportunities from the private sector are also required. They should be appropriately accompanied by R&I policy and continually evaluated with regard to their effects and significance for the education system.
- To be able to promote digital skills, they must be continuously monitored. The Commission of Experts therefore expressly welcomes Germany‘s participation in international comparison studies like ICILS or PIAAC to measure the key digital skills of both pupils and adults. Furthermore, the Federal Government should encourage the content-related further development of such studies.