Journal of Technical Education

Band 2, 2014, Heft 2

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Herausgeber

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Journal of Technical Education (JOTED)

ISSN 2198-0306

Online unter: http://www.journal-of-technical-education.de

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Technological literacy – Relevance spectrum, educational standards and research perspectives

Abstract

In the reference field relating to the increasing importance of a general basic technical education, new subjects - such as technology or science and technology - have also increasingly been introduced in the last few years within the grammar school sector. In the meantime, subjects are taught with a general technical educational programme in virtually all federal states. The following article describes key research perspectives for a basic technical education in grammar schools providing a general education – after an initial review of the fundamental relevance spectrum of the general technical education and an analysis of national and international educational policy documents on technical education.

Keywords: Technological literacy, science and technology, grammar school, professional didactic technology, educational standards

Technische Allgemeinbildung – Bedeutungsspektrum, Bildungsstandards und Forschungsperspektiven

Zusammenfassung

Im Bezugsfeld der wachsenden Bedeutung der allgemeinen technischen Grundbildung sind in den letzten Jahren verstärkt auch im gymnasialen Bildungssektor neue Fächer wie Technik oder Naturwissenschaft und Technik entstanden. In fast allen Bundesländern werden mittlerweile an allgemeinbildenden Gymnasien Fächer mit einem allgemeinen technischen Bildungsangebot unterrichtet. Der vorliegende Beitrag beschreibt, nach einem ersten Überblick zum grundlegenden Bedeutungsspektrum der technischen Allgemeinbildung und einer Analyse nationaler und internationaler bildungspolitischer Dokumente zur Technikbildung, zentrale Forschungsperspektiven für eine technische Grundbildung an allgemeinbildenden Gymnasien.

Schlüsselwörter: Technische Allgemeinbildung, Naturwissenschaft und Technik, Gymnasium, Fachdidaktik Technik, Bildungsstandards

1 Starting point

Technology is a formative part of our society and a significant factor, both in private and professional life. Technology exerts an influence on economic, environmental and cultural decisions; it has an influence on our health, ensures sustainable developments and initiates innovation processes. Technology responds to fundamental social challenges and provides us with mobility, communication and innovation. Technology is changing our habits, lifestyles and work processes; it is a blessing and burden at the same time. Technology undisputedly holds a key position for social change and determines how we see ourselves and the world. Given the multiple perspective of technology, it might be expected that a general technical education is also a key element of the curriculum of grammar schools providing a general education. A general technical education, which allows for a discussion on basic topics of general science and application-orientated technological questions. A general technical education, which allows students, on the one hand, to establish a fundamental technological knowledge base to evaluate social decisions, developments and the use of technology in relation to the intended and unintended consequences and uncertainties based on their knowledge and, on the other hand, enables students to acquire technical skills to adapt to the technical artefacts in private, social and professional situations. Given the relevance of technology, it might be assumed that the key importance of technology for our society would similarly involve an increase of interest in the technological field and a general technical education is firmly embedded in all levels of education, and therefore also in the grammar school sector. However, technology has only a relatively short history as a separate subject in grammar schools in Germany providing a general education. The development of science and technical education in the general school system in Germany is based on tradition, in particular as a result of discussions on formal and material eduction (for an overview, see for example, Lind 1996; Lind 1997; Blankertz 1967). Whereas there has been a technology or an integrative scientific/technical subject, such as science and technology at various levels of education, in primary schools, secondary schools and at college level in other countries, such as England, the Netherlands, Australia or the USA, for several years and sometimes also for several decades (see for example, Labudde 2005; for an overview, see de Vries 2012), subjects with explicitly technical curricula are relatively new in Germany in the grammar school sector providing a general education.

However, a growing momentum in the general technical education reference field has also been observed in grammar schools in Germany in recent years. Nearly all federal states have now introduced a subject in the grammar school sector providing a general education, which explicitly focuses on technical curricula (see for example, for north Rhine-Westphalia, the group of authors for the core curriculum for the upper secondary school level (*Sekundarstufe II*) for technology 2013; for Baden-Württemberg, the group of authors for the curriculum for grammar schools providing a general education 2004, Baden-Württemberg, P. 397-402; for Brandenburg, the group of authors for the framework plan for technology in the upper secondary level at grammar schools (*Sekundarstufe II*). Technology is taught individually in the lower and upper secondary school levels (*Sekundarstufe I/II*) at grammar schools providing a general education in the following federal states (table 1).

Federal state	*Subject name (secondary school level)*
Baden-Württemberg	Science and technology (I and II)
Bavaria	Nature and technology (I)
Berlin	Economics-work-technology (I)
Brandenburg	Economics-work-technology (I) Technology (II)
Hamburg	Science/technology (I)
Mecklenburg-Vorpommern	Work-economics-technology (I)
North Rhine-Westphalia	Technology (II)
Saarland	Technology (I and II)
Saxony	Technology/IT (I)
Saxony-Anhalt	Technology (I)
Schleswig-Holstein	Technology (I and II)
Thuringia	People-nature-technology (I) science and technology (I)

Tab. 1: Summary of federal states in which technology is taught at grammar schools providing a general education (source: database query from the Standing Conference of the Ministers of Education and Cultural Affairs (KMK), as of 01.10.2014).

A technical education, like virtually no other subject in the general education sector, is characterised by changing education policy and curriculum requirements and conditions, which is ultimately also illustrated by the different selection of subject names and the inconsistent range of subjects on offer at the upper secondary school level (table 1). While scientific subjects are legitimised in the grammar school sector from an educational theory and epistemological point of view and enjoy a long tradition (see for example, Schöler 1970), their subject-related reference points are fixed in educational standards and school type and state-specific curricula, they can rely on elaborate domain-specific research and studies for measuring and modelling skills are available (for an overview, see for example, Kauertz et al. 2010) and also the general technical education in the middle school and secondary modern school sectors (Hauptschule/Realschule) can now attest to a tradition[1] (see for example, Schmayl & Wilkening 1995), the teaching and research for a general technical education in the grammar school sector is still largely in its infancy in this respect. This article focuses on key research perspectives for a basic technical education in grammar schools providing a general education after an initial review of the relevance spectrum of a general technical education and an analysis of national and international education policy documents on technical education.

2 Relevance spectrum of a general technical education

There are countless publications on the legitimacy and emancipation of a general technical education. A comprehensive explanation should be avoided at this point as this has already been described in detail in other places (see for example, Wagenschein 1965; Roth 1965; Ropohl 1971; Ropohl 1976; Pfenning & Renn 2012). Nevertheless, it seems appropriate to briefly outline the relevance spectrum of a general technical education in view of the multiple reference perspectives and their implications on the theoretical classification of the research areas defined in the fourth section and deemed relevant. The following reference perspectives can be quoted in a rough division to classify the relevance of a general technical education: (a) Educational theory relevance (see for example, Wagenschein 1965; Roth 1965; Ropohl 1971; Rehm et al. 2008; Ropohl 2004; Blankertz 1967), (b) Epistemological relevance (see for example, Ropohl 1976; Spur 1998; Ropohl 2004; Banse et al. 2006; Banse 2007; Pfenning & Renn 2012; Graube 2014), (c) Sociological relevance (see for example, Postman 1992; Pfenning & Renn 2012; de Vries 2012) and (d) Practical educational relevance (see for example, Geißel et al. 2013; Harms, Eckhardt & Bernholt 2013; Zinn 2015).

ad (a) Educational theory relevance: The educational theory standpoint of a general technical education is essentially based on two key requirements: firstly that students in the school must be prepared for society and life and secondly, that technology represents a constitutive part of our culture. At this point it is assumed that technology is subjected to dynamic developments and should be made available in numerous and diverse ways within the educational structures as part of the personal experiences in the world we live in. The educational potential of

[1] Technical curricula have been taught in the middle school and secondary modern school sectors since the 1960s/1970s (see for example, Schmayl & Wilkening 1995; Schudy 2001; Ropohl 2004). Technical curricula can be found in the middle school and secondary modern school sectors: (1) Traditionally in the subject of business studies and/or subjects related to this, such as profession-budgeting-technology-economics or work-economics-technology; the curricula include elements of a basic artisanal and IT education, amongst other things, for the technical part of the subject and focus on career guidance (Ziehfuss 1998; interdisciplinary working group for the subjects of profession-budgeting-technology-economics for the lower secondary school level 2006). (2) In the separate subject of technology (see for example, the group of authors for the subject curriculum for technology in secondary schools 2012, Saxony-Anhalt; the group of authors for the curriculum for secondary modern schools 2004, Baden-Württemberg, P. 143-148). (3) In topic-orientated project arrangements, such as technical work, where the focus lies particularly on supporting the handling of materials and technical artefacts (see for example, ibid., P. 175-177). (4) In integrative subjects (and also some subjects that are taught across all school years), such as nature and technology (for example, in Bavaria; see for example, Göhring, Haider & Streubert 2010).

technology consists of the appropriation of technology through understanding and construction as well as in the evaluation and design of technology, amongst other things. The promotion of social participation is considered a key educational goal of technological literacy in the creation of the Standards for Technological Literacy by the International Technology Education Association (ITEA). "From a personal standpoint, people benefit both at work and at home by being able to choose the best products for their purposes, to operate the products properly, and to provide troubleshooting when something goes wrong. And from a social standpoint, informed citizenry improves the chances that decisions about the use of technology will be made rationally and responsibly" (ITEA 2007, p. 2). Education through technology is portrayed as a subcategory of a superior claim, namely education through culture, in the educational theory perspective. Taking into account the general relevance of technology in a technologically-orientated society, the educational theory perspective implies that education through technology is a standalone domain of modern society, which is characterised by technology in everyday life and in its rational thinking, which ultimately aids active participation in society (see for example, Wagenschein 1965; Roth 1965; Ropohl 1971; Rehm et al. 2008; Ropohl 2004; Blankertz 1967; ITEA 2007).

ad (b) Epistemological relevance: General scientific technology (or general technology) was established at the start of the 19th century by the Göttingen-based state scientist Johann Beckmann (Beckmann 1806). According to Banse et al. (2006, 337), general scientific technology includes "generalist transdisciplinary technological research and technical teaching and is the science of general functional and structural principles of subsystems and their socio-cultural contexts of origin and use". General scientific technology is therefore regarded as a separate science (see for example, Ropohl 1976; Spur 1998; Ropohl 2004; Banse et al. 2006). Scientific technology is interdisciplinary; it corresponds closely to sciences, engineering sciences (e.g. structural engineering, electrical engineering) as well as other domains, such as philosophy, sociology and economics. Ultimately, the interdisciplinarity and interlinking of technology with other domains is also very evident in the academic differentiations of individual scientific disciplines, such as the philosophy, sociology or ethics of technology (see for example, Grunwald 2002; Schanz 2003; Banse et al. 2006). The interdisciplinarity of scientific technology has key implications on research and teaching. While sciences are traditionally considered basic sciences, scientific technology was just regarded as an applied science, mathematical-scientific knowledge or as a pure design or problem-solving science for a long time. The advances in knowledge in sciences were however increasingly due to technological advances (e.g. genetic engineering in microbiology). Looking at the newer areas of science, such as biotechnology, bioinformatics, building physics, photonics, life sciences and synthetic biology (see for example, Pühler, Müller-Röber & Weitze 2011), which are common to sciences and scientific technology, it becomes evident that many traditional scientific areas have already merged into new ones and a symbiotic differentiation can be made between them. Technology is therefore opening up a new interdisciplinary understanding in the modern scientific society and is not just a pure design and empirical science, but also a basic science in itself (see for example, Spur 1998; Banse 2007; Graube 2014; see also Gehring 2013 for the implications of the interdisciplinarity on teaching and research).

ad (c) Sociological relevance: From a sociological perspective, the key importance of a general technical education is primarily focused on the acquisition of a general technical understanding and an individual technological maturity as well as on epistemological emancipation. (see for example, Pfenning & Renn 2012; Pfenning 2013). New technologies, such as genetic engineering or the Internet, clearly show that technology is not just a constitutive element of modern society, but technology itself can also become a significant factor of social change and determines technology driven processes of change. New technologies can destabilise organisations and structures and trigger social changes (see for example, Postman 1992; Rammert 2007; Dolata 2011; de Vries 2012).

ad (d) Practical professional relevance: Looking at the empirical state of research on the correlations between general technical and scientific skills and abilities acquired at school and professional skills, three areas of research can be differentiated. Firstly, it is assumed in the intelligence research reference field that specific skills, such as technical skills, in addition to general intelligence, explain the success of education (e.g. Ackerman 1996, 2003; Schmidt-Atzert, Deter & Jaeckel 2004). In general intelligence, general technical skills are considered part of the crystalline intelligence facet and are regarded as significant for the acquisition of professional skills (for an overview, see for example, Abele 2014). Secondly, the success of education and/or the state of knowledge when making a transition into education is evaluated depending on tests geared towards technical curricula or the predictive effect of school grades (e.g. Schuler, Funke & Baron-Boldt 1990; for an overview, see also Abele 2014). Thirdly, general technical and scientific skill facets are included as previous subject-specific knowledge in the explanation of the development of domain-specific skills in education and further training in the studies on the development of professional skills (see for example, Nickolaus et al. 2010; Zinn & Wyrwal 2014). In studies investigating the correlations between general technical skills acquired at school and the development of professional skills it becomes apparent that different curricula in the basic school education are effective due to the job-specific requirements in the professional fields (e.g. structural engineering, chemical engineering, electrical engineering) and at the individual professional level (see Geißel et al. 2013; Harms, Eckhardt & Bernholt 2013; Zinn 2015). If the empirical evidence in the transitional area between general and professional education is still generally unsatisfactory (ibid.), the available findings are based on a positive correlation between the technical and scientific skills acquired at school and a successful initial professional education. It is therefore determined in all three areas of research and also seems theoretically plausible that there are significant correlations between a basic technical education[2] and the development of professional skills and especially the commercial/technical professions in this respect.

In summary, it should be noted that the educational theory, epistemological, sociological and practical profession perspectives result in a variety of implications for the teaching and research for a general technical education. For example, questions arise regarding fulfilling

[2] The importance of a general technical education is also derived from a school's general educational mandate. According to the statutory educational mandate, the school is required to prepare the students for the requirements of (technical) business and working life with their different tasks and developments (see § 1 (2) of the Education Act for Baden-Württemberg, version dated 01.08.1983, GBl. P. 397).

complex objectives associated with the perspectives. How can technological maturity be taught with a focus on skills in a general technical education? What technological maturity skill levels can be empirically demonstrated by students in the grammar school system or what are the consequences of strong technological interdisciplinarity for school teaching practice and skills development. Is the general interest in technology and also the willingness to pursue a technical degree positively encouraged by learning an additional technology subject at grammar school? Although the relevance spectrum of a general technical education as outlined is simplistic and, as stated at the outset, also does not claim to be complete, it can be extended both quantitatively (with additional perspectives) or qualitatively (with additional perspective facets) if there are several significant links for research in the reference field (see section 4). The following section considers whether and how the individual perspectives reflect with their different yet complex implications in the current education policy documents.

3 Educational standards of a basic general technical education

The main objectives of the educational standards are to ensure the results of a school and the improvements in the quality or teaching through educational monitoring. The subject-specific objectives are formulated in terms of skills and regulatory standards in the individual domain-specific educational standards (see for example, Walpuski et al., 2008). According to the much-cited definition by Weinert (2001), skills are "the cognitive abilities and skills that individuals possess or can learn for solving specific problems and the associated motivational, volitional and social readiness and abilities that enable them to use these solutions responsibly and successfully in a variety of situations" (Weinert 2001, P. 27). According to Klieme et al. (2003), it is assumed that skills should be modelled on a domain-specific basis, where the domain definition is not clear-cut and can relate to individual subjects, such as technology or a group of subjects, such as science and technology. While there have been cross-border agreements on the educational standards (intermediate secondary education qualification) for the traditional scientific subjects physics, biology and chemistry for nearly a decade and empirical skill modelling also already exists (see for example, Kauertz et al., 2010; Ramseier, Labudde & Adamina 2011), there are no cross-border educational standards for the subject of technology. Standards for a general technical education and/or a general scientific technological education are derived from the policy papers of interest groups (e.g. ITEA 2003; AAAS1994; VDI 2007) and state-specific curricula (see for example, for North Rhine-Westphalia, the group of authors for the core curriculum for the upper secondary school level (*Sekundarstufe II*) for technology 2013).

In order to subsequently outline the curricular implications for the teaching and research for a general technical education, a selection of national and international education policy documents (standards and curricula), which are considered relevant, will be presented below in addition to an international study on a general technical education. The following will be considered in particular: (1) The Delphi-study by Rossouw, Hacker and de Vries (2011), (2) The standards for technological literacy issued by the International Technology Education Association (ITEA 2007), (3) The integrative approach of the American Association for the

Advancement of Science (AAAS 1994), (4) The educational standards of the Association of German Engineers for the subject of technology (VDI 2007) and (5) The curriculum for the grammar school subjects of science and technology (the group of authors for the curriculum for grammar schools providing a general education 2004, Baden-Württemberg, P. 397-402).

(1) Delphi study by Rossouw, Hacker and de Vries (2011)

Rossouw, Hacker and de Vries (2011) carried out a Delphi study, in which the key objectives of a basic technical education that were deemed to be desirable were analysed, to support in particular the conceptualisation of curricula for the subject of technology with regard to its core content. The focus of the established international and interdisciplinary Delphi study was on the subject cluster of ETE[3] (engineering and technology education). 32 international experts from the education, philosophy, history and communication of technology from schools and higher education took part in the study. The following five main concepts (with sub-concepts in brackets) were established based on the results of the survey and other iteration steps for the conceptual design: (1) Designing (optimising, trade-offs, specifications, invention, product life cycle), (2) Systems (artefacts, structure, function), (3) Modelling (4) Resources (materials, energy, information), (5) Values (sustainability, innovation, risk/failure, social interaction and technology assessment (ibid., P. 422). Furthermore, the experts considered nine everyday contexts in the Delphi study that were relevant for the development of educational standards for a general technical education: (1) Shelter (‘construction’), (2) Artefacts for practical purposes, (3) Mobility (‘transportation’), (4) Communication, (5) Health (‘biomedical technologies’), (6) Food, (7) Water, (8) Energy and (9) Safety (ibid., P. 421).

(2) Standards for technological literacy from the International Technology Education Association (ITEA 2007)

The International Technology Education Association (ITEA) described standards for a general technical education (ITEA 2000) for the first time at the turn of the millennium. Standards for technological literacy (STL)[4] include a comprehensive educational programme from preschool to the end of the upper secondary school level (Class 12). The STL are based on a literacy concept, do not form a binding curriculum and are also not considered static and unchangeable; instead, the STL are subjected to periodical re-evaluations and should serve as a basis for the creation of educational standards for the institutions responsible for the curricula (ITEA 2000, 2003, 2007). The functional and pragmatic-orientated literacy concept based on the PISA tests defines the objectives of a basic education in general terms and focuses less on formal existing knowledge, but rather on orientation and practical knowledge. The ITEA defines technological literacy as follows: "Technological literacy is the ability to use, manage, assess, and understand technology. A technologically literate person understands, in increasingly sophisticated ways that evolve over time, what technology is,

[3] The Delphi study should not explicitly refer to the subject cluster of STEM (science, technology, engineering, and mathematics) (Rossouw, Hacker & de Vries 2011, 410)

[4] The ITEA standards (2000, 2003) are also translated into German (Höpkgen, Osterkamp & Reich 2003, 2004).

how it is created, and how it shapes society, and in turn is shaped by society. He or she will be able to hear a story about technology on television or read it in the newspaper and evaluate the information in the story intelligently, put that information in context, and form an opinion based on that information, A technologically literate person will be comfortable with and objective about technology, neither scared of it nor infatuated by it (ITEA 2007, 9f.). In particular, the STL include 20 standards that are grouped in five clusters: The first cluster "Properties of technical products and processes" (standards 1-3) basically includes the essence of technology, basic technological terms and the correlations between technology and other areas of life. The second cluster "Correlations between technology and society" (standards 4-7) focuses in particular on the cultural, social, economic and socio-historic impact of technology. The third cluster "Design and construction of technical products" (standards 8-10) considers technical designs, the construction process and the importance of troubleshooting, from research and development, invention and innovation and from experiments to solving a problem. The fourth cluster "Necessary skills for life in a technical word" (standards 11-13) includes the construction, use and maintenance or technical products and systems as well as the evaluation and impact of technology. The fifth cluster "Technical world" (standards 14-20) describes standards for the acquisition of knowledge, skills in the technical areas of medical engineering, agricultural technologies, biotechnology, power engineering, information and communications technology, transport engineering, production technology and structural engineering.

(3) Standards of the American Association for the Advancement of Science (AAAS 1994)

An integrative approach for a scientific, mathematical and technical education is founded in project 2061 carried out by the American Association for the Advancement of Science (AAAS 1994). Project 2061 has its origins in the science technology society movement in the 1960s (see Walberg 1991). Minimum standards (benchmarks) are formulated for twelve subject areas[5] across four levels of education with this conceptualisation[6], from nursery school through to school year 12. There are numerous links between the individual subject areas, which connect the mathematic, scientific and technological perspectives with each other without the characteristics of the respective technical approaches being abandoned (AAAS 1994) - this is the explicit claim of the AAAS. "The nature of technology" subject, specifically geared towards technology, encompasses the following clusters: (1) Technology and science, (2) Design and systems and (3) Issues in technology. The minimum standards for the clusters for school years 9 - 12 are outlined below:

(1) Technology and science

- Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their

[5] The following levels of education in particular exist: nursery school to school year 2, school years 3 to 5, school years 6 to 8, school years 9 to 12 (AAAS 1994)

[6] The subject areas encompass the following: the nature of science, the nature of mathematics, the nature of technology, the physical setting, the living environment, the human organism, human society, the designed world, the mathematical world, historical perspectives, common themes and habits of the mind.

research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.

- Mathematics, creativity, logic, and originality are all needed to improve technology.
- Technology usually affects society more directly than science does because technology solves practical problems and serves human needs (and also creates new problems and needs).
- One way science affects society is by stimulating and satisfying people's curiosity and enlarging or challenging their views of what the world is like.
- Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behaviour of things will be even before they are made. Moreover, science often suggests new kinds of behaviour that had not even been imagined before, and so leads to new technologies.

(2) Design and systems

- When designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
- The value of any given technology may vary for different groups of people and at different points in time.
- Complex systems have layers of controls. Some controls operate particular parts of the system and some regulate other controls. Even fully automatic systems require human control at some point.
- Risk analysis is used to minimise the likelihood of unwanted side effects of a new technology. However, the public perception of risk may depend on psychological factors as well as scientific ones.
- The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures.
- Performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be the least reliable to reduce the chance of system failure.

(3) Issues in technology

- Social and economic forces strongly influence which technologies will be developed and used. Those that will prevail are affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition and tax incentives.
- Some scientists and engineers are comfortable working in situations in which some secrecy is required, but others prefer not to do so. It is generally regarded as a matter of individual choice and ethics, not one of professional ethics.

- When deciding on proposals to introduce new technologies or curtail existing ones, some key questions arise concerning possible alternatives, who benefits and who suffers, financial and social costs, possible risks, resources used (human, material, or energy) and waste disposal.
- The human species has a major impact on other species in many ways: reducing the amount of the earth's surface available to the other species, interfering with their food sources, changing the temperature and chemical composition of their habitats, introducing foreign species into their ecosystems and altering organisms directly through selective breeding and genetic engineering.
- Human inventiveness has brought new risks as well as improvements to human existence.
- The human ability to influence the course of history comes from its capacity to generate knowledge and develop new technologies and to communicate ideas to others.

(4) Educational standards for the subject of technology from the Association of German Engineers (VDI 2007)

The recommendations developed by the Association of German Engineers (VDI 2007) assume five skill areas: (1) Understanding technology (goal orientation and functions, concepts, structures, knowing and applying the principles of technology (2) Designing and producing technology (planning, designing, producing, optimising, inspecting and testing technical solutions), (3) Using technology (selecting technical solutions, applying and disposing of them in compliance with technical and safety requirements), (4) Evaluating technology (evaluating technology based on historical, ecological, economical, social and humane perspectives) and (5) Communicating technology (developing and exchanging information relevant to technology with reference to the issues, subjects and target groups). The standards defined in the recommendations are structurally geared towards the educational standard of the sciences and explicitly refer to everyday areas of activity, such as "Building and living", "Transport and traffic" or "Supply and disposal". The standards provided for the five skill areas each include three levels of requirements (ibid., P. 8ff.). According to the conceptions of the VDI, technology lessons should develop components, which are needed to cope with technology-orientated situations in life, to create the conditions for personal lifestyles and social participation. Technology lessons should also contribute towards the "preparation for coping with the demands of today's technology in private, professional and public life" (ibid., P. 7). According to the recommendations, a general technical education should in particular provide a tangible focus in the use of materials, energy and information, give an introduction to the methods and types of actions for technology in the areas of planning, designing, producing, evaluating, utilising and disposal, provide an understanding of the structures and functions of technical subsystems and processes as well as the conditions and consequences of technology and encourage the development of interest in technology as well as creativity through technical problem solving processes (ibid., P. 5).

(5) Curriculum for the subject of science and technology (NwT, Baden-Württemberg)

The teaching of science and technology (*NwT*) in grammar schools in Baden-Württemberg providing a general technical education[7] also offers an integrative conceptualisation of a technical education in the context of a scientific education. The subject of science and technology does not substitute the subjects of physics, biology, chemistry and geography, but rather is taught as an additional subject in grammar schools. The science and technology curriculum for the middle school level focuses on three principles (causes and effect, system concept as well as energy conservation) and a differentiation is made in particular between four areas of interest (people, the environment, technology and well as earth and space). Students should possess the following skills in the area of technology after completing school year 10: analyse and evaluate energy utilisation opportunities, understand and assess aspects of energy supply, produce a product in a biotechnical process and record process technological parameters, produce an everyday product by means of a chemical technological process, explain the static structure of a building, apply mechanical design and operating principles, recognise and describe analogies between technical and natural systems and be familiar with nanotechnology and IT applications (the group of authors for the curriculum for grammar schools providing a general education 2004, Baden-Württemberg, P. 397-402). The science and technology curriculum for the upper secondary school level should explicitly provide in-depth knowledge of the general technical education content provided at middle school level (the group of authors for the design of the educational standards 2011, science and technology curriculum at upper secondary school level in Baden-Württemberg, S. 1-4). Four skill areas are defined in the upper secondary school level curriculum: (1) Cognitive area (acquire, classify and transfer knowledge), (2) Area of action (apply knowledge, design, produce and use products), (3) Communicative area (record, present and share information) and (4) Evaluation area (evaluate products and the associated processes as well as their consequences in a professional manner). A limited systematically recorded observation and description are currently available for the implementation of the school curriculum (Mokhonko, Ștefănică und Nickolaus 2014, P. 10). The subjects of "Technical use of renewable energy sources, bridge construction, robotics and medical engineering" are handled in the technology curriculum (ibid.).

Although the education policy documents outlined vary significantly with regard to their origin and scope as well as their individual qualitative and quantitative layout, the following general characteristics can nevertheless be determined: (a) The subject areas and/or clusters for a general technical education are based on (current) everyday contexts and areas of activity. (b) The focus of the description is not so much on a subject classification. Technical

[7] The integrative subject of science and technology (*NwT*) was already introduced back in 2007/2008 as a profile subject of the scientific profile of the grammar school in school years 8 to 10 in all schools across Baden-Württemberg. As a core subject, science and technology therefore corresponds to the third foreign language in the linguistic profile and is taught for four periods (the group of authors for the curriculum for grammar schools providing a general education 2004, Baden-Württemberg, P. 397-402). The subject of science and technology is also currently being taught for two periods in school years 11 and 12 in several schools as part of a pilot programme.

content is only implicitly described. (c) There is a focus on the literacy concept[8]. The objectives of a basic technical education are general in nature and focus less on available knowledge, but refer to orientational and practical knowledge. (d) The subject areas outlined in the documents include a close link to engineering domains, such as structural engineering, electrical engineering or mechanical engineering. (e) The structural design of the skill areas (cognitive area, area of action, communicative area and evaluation area) in the national documents presented is largely identical to the structure of the skill areas in the scientific subjects[9]. (f) Most areas of the conceptualisations refer to an action-orientated implementation and problem-orientated approaches.

5 Research perspectives

An evidence base for a basic general technical education is required in several areas and across all school years (see for example, Höpken, Osterkamp & Reich 2003; Buhr & Hartmann 2008; Euler 2008; Mokhonko, Ştefãnică & Nickolaus 2014). The available articles on a general technical education have mainly been of a conceptual and descriptive nature up until now and rarely empirical. However, the few partial studies available (see for example, Meschenmoser 2009; Meier 2009; Wahner 2009; Urban-Woldron & Hopf 2012; Gerstner 2009; Walker 2013; Stemmann & Lang 2014) can offer starting points for an additional evidence base for the subject of technology. Contributions in the context of skill diagnostics from students learning a general technical education also largely relate to conceptual aspects (for an overview, see for example, Theuerkauf et al. 2009). A limited evidence-based observation and description for the subjects of technology or science and technology are available particularly for the grammar school sector (see for example, Mokhonko, Ştefãnică & Nickolaus 2014). There are key research perspectives in particular on technological literacy at grammar schools providing a general education in our opinion:

(1) *To further develop (phased) didactics for the subject of technology at grammar schools providing a general education:* Up until now, we have had to largely rely on the use of research findings on scientific subjects and subject clusters, which are assigned to the secondary school level sector (e.g. work-economics-technology), with subject didactic decisions, given the inadequate state of research. The findings on the state of research provide evidence, but this is only of limited use for specific subject-didactic education in the teaching of technology and/or science and technology at grammar schools due to the specific subject profiling and given the different school types and school year levels. A limited observation and description for the subject-specific teaching and learning processes in the subject of technology at grammar schools have been available up until now (see for example, Walker 2013; Mokhonko, Ştefãnică & Nickolaus 2014). It still

[8] A shift of the subject classification towards general educational topics is also stipulated for the scientific school curriculum (see for example, Euler 2008).

[9] The educational standards for the scientific subjects of biology, chemistry and physics each have the same structure and encompass four skill areas: subject knowledge, acquisition of knowledge, evaluation and communication (KMK 2005a; KMK 2005b; KMK 2005c).

remains to be seen what the general technical education at grammar schools will actually achieve and how it will fulfil its specific propaedeutical demands. Given the broad spectrum of general technical education (see above), it would be meaningful to empirically clarify how the theoretical approaches in educational practice in grammar school education can contribute to the desirable development of subject-related skills and promote scientific technological skill facets, such as technological maturity or an interest in technology, without being restricted to purely technology application-orientated skill facets for the conceptual further development of the existing didactic approaches and concepts[10].

(2) *To measure skills:* Technical educational standards can only be effective for quality assurance if appropriate valid performance tests can be developed on the basis of the skills behind them. An established skills model (framework model) is necessary for the development of subject-specific performance tests; this should include information about the design of levels and a nomological network in addition to relevant skill areas and specific skill facets, which specifies the relationship between the respective technical skills and other structures. The formation of nomological networks appears significant especially for the subject clusters in which technical curricula are conveyed in integrative conceptualisations (e.g. the subject of science and technology). It is necessary to clarify whether the normative-based educational standards are actually domain-specific and can be empirically replicated. A comprehensive analysis of the school-specific curricula and subjects should be beneficial in addition to the analysis of individual state-specific educational standards for creating a framework model and for developing tests to identify core curricular subjects.

(3) *To structure and develop skills:* The question also arises in the reference field as to whether the general technical skills acquired at school are portrayed empirically separated in individual dimensions or are depicted in a common factor. For example, can the skills structure of a single technology lesson also be replicated for integrative concepts for teaching technology (e.g. the subject of science and technology)? With an integrative conceptualisation of general technical education there is a risk that key technological perspectives, characteristics and typical working methods are not adequately considered and technology is therefore largely limited to the aspect of applied science (see for example, Euler 2008). The following questions therefore arise: What empirical correlations exist between scientific and technical skills and how is the growth in skills development actually portrayed, taking onto account the curricular requirements and practical implementation in schools (e.g. singular or integrative)?

(4) *To predict an interest in studying and study success and/or an interest in education and educational success:* Given the fact that an interest in science and technology is

[10] In general, a differentiation is made between three theoretical approaches for the teaching of technology: The work-orientated approach and the multi-perspective approach were primarily developed for middle, secondary modern and comprehensive schools and the general technological approach was developed for the upper secondary school level at grammar schools (Schmayl 2003, 131f.).

traditionally afforded a special role in academic practice (see for example, Lehrke 1988; Hoffmann, Häußler & Lehrke 1998; for an overview, see for example, Zinn 2008, 4-52), the analysis of students' interest should be a focus of research in the context of the subjects of technology and/or science and technology in grammar schools. In addition, in the transitional stage from school into a profession or from school into higher education, it would be necessary to clarify the significance of general technical skills acquired at school for a choice of study or profession as well as the acquisition of professional skills in relation to other cognitive, motivational and volitional measures as well as indicators of the family background.

(5) *To further develop teacher training:* Professional knowledge (subject-didactic knowledge, pedagogical knowledge, organisational knowledge and counselling knowledge), beliefs/values, motivational orientations and self-regulatory skills are proven to be significant in current models relating to teachers' skills (see for example, Shulman 1987; Krauss et al. 2004). Given the broad spectrum of reference disciplines relating to the subjects of technology and/or science and technology (including biology, chemistry, physics, structural engineering, electrical engineering, IT, sociology) and the requirements for propaedeutics in grammar schools, this raises a question regarding the teachers' scientific skills and professional didactic profile. Given the key importance of the teachers' technical knowledge for the educational process (see for example, Hattie 2013; Baumert & Kunter 2013) and the limited allocation of time in teacher training, there is potentially a structural problem to acquire extensive knowledge, meaning that only elementary technical knowledge and basic technical skills can be developed in the relevant reference disciplines within the framework of the study programme (Nickolaus & Zinn 2013). It is necessary to elaborate on the key scientific skills and professional didactic profile that technology teachers in grammar school education need to have after their first and second phases of teacher training within the context of this subject matter in order to satisfy the scientific and professional didactic requirements in the context of the objectives for the subject of technology and the propaedeutical requirements in a desirable manner.

In conclusion, the evidence-based research regarding a general technical education is challenging given the complex relevance spectrum, range of interlinked reference disciplines, comprehensive and multi-faceted educational standards as well as taking into account the common overlap in subjects in academic practice. An evidence base of the general technical education at grammar schools could promote structural further development of the subject in this education segment despite the set of challenges. Empirically reliable evidence on educational outcomes and the actual importance of a general technical education in grammar schools could appear beneficial for the origins in the reference field, not least because of the educational potential of technology, which is still often undervalued.

6 References

AAAS [American Association for the Advancement of Science] (Ed.) (1994). Benchmarks for Science Literacy. Oxford: University Press.

Abele, S. (2014). Modellierung, Entwicklung und Determinanten berufsfachlicher Kompetenz in gewerblich-technischen Ausbildungsberufen. Analysen auf Basis von testbasierten, berufsschulischen und betrieblichen Leistungsdaten sowie Prüfungsergebnissen. Stuttgart: Steiner.

Ackerman, P. L. (1996): A theory of adult intellectual development: Process, personality. interests, and knowledge. Intelligence, 22, S. 227–257.

Autorengruppe Bildungsplan 2004 Allgemein bildendes Gymnasium (2004). Ministerium für Kultus, Jugend und Sport Baden-Württemberg (Hrsg.). (S. 397-402). Online: http://www.bildung-staerkt-menschen.de/service/downloads/Bildungsplaene/Gymnasium/ Gymnasium_Bildungsplan_Gesamt.pdf (22.08.2014).

Autorengruppe Entwurf für Bildungsstandards (2011). Entwurf für Bildungsstandards Naturwissenschaft und Technik (NwT) Kursstufe 2-stündig. Landesinstitut für Schulentwicklung (S. 1-4). Online: http://www.bildung-staerkt-menschen.de/service/ downloads/Bildungsstandards/Gym/Gym_ NwT_kurs_2st_bs.pdf (27.08.2014).

Autorengruppe Bildungsplan 2004 Realschule (2004). Ministerium für Kultus, Jugend und Sport Baden-Württemberg (Hrsg.). (S. 143-148). Online: http://www.bildung-staerkt-menschen.de/service/downloads/Bildungsplaene/Realschule/Realschule_Bildungsplan_Gesamt.pdf (22.08.2014)

Autorengruppe Fachlehrplan Sekundarschule Technik (2012). Kultusministerium des Landes Sachsen-Anhalt (Hrsg.). Online: http://www.bildung-lsa.de/pool/RRL_Lehrplaene/ Endfassungen/lp_sks_tech.pdf (22.08.2014).

Autorengruppe Kernlehrplan für die Sekundarstufe II Technik Gymnasium/Gesamtschule in Nordrhein-Westfalen Technik (2013). Herausgegeben vom Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen (Hrsg.). Online: http://www. standardsicherung.schulministerium.nrw.de/lehrplaene/upload/klp_SII/tc/GOSt_Technik_Endfassung.pdf (22.08.2014).

Autorengruppe Rahmenplan Technik Gymnasiale Oberstufe Sekundarstufe II (1994). Herausgegeben vom Ministerium für Bildung, Jugend und Sport des Landes Brandenburg. Potsdam: Brandenburgische Universitätsdruckerei und Verlagsgesellschaft Potsdam.

Banse, G. (2007). Technikwissenschaften – Wissenschaften vom Machen. In: Parthey, H. & Spur, G. (Hrsg.): Wissenschaft und Technik in theoretischer Reflexion. Frankfurt am Main u.a.: Lang, S. 131-150.

Banse, G., Grunwald, A., König, W. & Ropohl, G. (Hrsg.) (2006): Erkennen und Gestalten. Eine Theorie der Technikwissenschaften. Berlin: Ed. Sigma.

Baumert, J. & Kunter, M. (2013). Stichwort: Professionelle Kompetenz von Lehrkräften. Zeitschrift für Erziehungswissenschaft 4, S. 469-520.

Beckmann, J. (1806). Entwurf der allgemeinen [sic!] Technologie. In: Beckmann, J.: Vorrath kleiner Anmerkungen über mancherley gelehrte Gegenstände. Stück 3. Göttingen: Röwer, S. 463-533.

Bienia, D. (2005). Der mehrperspektivische Ansatz der technischen Bildung Probleme und Perspektiven im Hinblick auf die Neuausrichtung der Schule. Zeitschrift für Technik im Unterricht, TU 115, S. 5-14.

Blankertz, H. (1967). Zum Begriff des Berufs in unserer Zeit. In: Blankertz, H. (Hrsg.): Arbeitslehre in der Hauptschule. Essen. S. 9-27.

Buhr, R. & Hartmann, E. A. (Hrsg.) (2008). Technische Bildung für Alle. Ein vernachlässigtes Schlüsselelement der Innovationspolitik. Institut für Innovation und Technik. Berlin: VDI/VDE Innovation + Technik GmbH, Berlin.

De Vries, M. (2012). Teaching for scientific and technological literacy - an international comparison. In: U. Pfenning & O. Renn (Hrsg.), Wissenschafts- und Technikbildung auf dem Prüfstand. Zum Fachkräftemangel und zur Attraktivität der MINT-Bildung und -Berufe im europäischen Vergleich. Baden-Baden: Nomos. S. 93-110.

Dolata, U. (2011). Wandel durch Technik. Eine Theorie soziotechnischer Transformation. Frankfurt/New York: Campus Verlag.

Duismann, G.H. & Meschenmoser, H. (2009). Technisches Verständnis als arbeitsrelevante Basiskompetenz. Empirische Befunde zur Kompetenzdiagnostik technischer Grundbildung. In Qualität Technischer Bildung. Kompetenzmodelle und Kompetenzdiagnostik. Schriften zur Arbeit-Beruf-Bildung, Bd.3, S.104-125.

Euler, M. (2008). Situation und Maßnahmen zur Förderung der technischen Bildung in der Schule. In: Buhr, R. & Hartmann, E. A. (Hrsg.): Technische Bildung für Alle. Institut für Innovation und Technik. Berlin: VDI/VDE Innovation + Technik GmbH. S. 67-104.

Geißel, B., Nickolaus, R., Ştefãnică, F., Härtig, H. & Neumann, K. (2013). Die Relevanz mathematischer und naturwissenschaftlicher Kompetenzen für die fachliche Kompetenzentwicklung in gewerblich-technischen Berufen. In: Nickolaus, R., Retelsdorf, J., Winther, E. & Köller, O. (Hrsg.): Mathematisch-naturwissenschaftliche Kompetenzen in der beruflichen Erstausbildung. Zeitschrift für Berufs- und Wirtschaftspädagogik. (ZBW) Beiheft 26, S. 39-65.

Gehring, P. (2013): Technik in der Interdisziplinaritätsfalle – Anmerkungen aus Sicht der Philosophie. Journal of Technical Education (JOTED), 1(1), S. 132-146.

Gerstner, S. (2006). Eine empirische Studie zum Einsatz von schülerzentrierten Unterrichtsmethoden im Natur- und Technik-Unterricht zum Thema „Wasser – Grundlage des Lebens“. Dissertation Universität Bayreuth.

Göhring, A., Haider, M. & Streubert, M. (2010). Naturwissenschaft und Technik (NWT) – ein neues integriertes Didaktikfach in der Lehrerausbildung. Frühjahrstagung der Didaktik der Physik in Hannover 2010.

Graube, G. (2014). Wissenschaft und Technik. Zur Reflektion von Technoscience und Interdisziplinarität in der Allgemeinbildung. Journal of Technical Education (JOTED), 2 (1), S. 129-148.

Grunwald, A. (2002). Technikethik. In: Düwell, M., Hübentahl, C. & Werner, M., H. (Hrsg.): Handbuch Ethik. (S. 277-281). Stuttgart: Metzler.

Harms, U., Eckhardt, M. & Bernholt, S. (2013): Relevanz schulischer Kompetenzen für den Übergang in die Erstausbildung und für die Entwicklung beruflicher Kompetenzen: Biologie- und Chemielaboranten. In: Nickolaus, R., Retelsdorf, J., Winther, E. & Köller, O. (Hrsg.): Mathematisch-naturwissenschaftliche Kompetenzen in der beruflichen Erstausbildung. Zeitschrift für Berufs- und Wirtschaftspädagogik (ZBW), S. 111-134. Beiheft 26. Stuttgart: Steiner.

Hartmann, E. (2007). Bildungsstandards für das Fach Technik. Empfehlungen des Vereins Deutscher Ingenieure. Unterricht: Arbeit + Technik. Heft 35. S. 45-48.

Hattie, J. (2013). Lernen sichtbar machen. Überarbeitete deutschsprachige Ausgabe von Visible Learning von Beywl, W. & Zierer, K., Hohengeheren: Schneider.

Heymann, H. W., van Lück, W., Meyer, M., Schulze, Th. & Tenorth, H.-E. (1990). Allgemeinbildung als Aufgabe der öffentlichen Schule. In: Heymann, H.W. & van Lück, W. (Hrsg.): Allgemeinbildung und öffentliche Schule: Klärungsversuche (S. 9-20). Bielefeld: IDM.

Heymann, H. W. (1996). Allgemeinbildung und Mathematik. Weinheim, Basel: Beltz Verlag.

Hoffmann, L., Häußler, P. & Lehrke, M. (1998). Die IPN-Interessenstudie Physik, Kiel: Institut für die Pädagogik der Naturwissenschaften (IPN).

Höpken, G., Osterkamp, S. & Reich, G. (Hrsg.) (2003). Standards für eine allgemeine technische Bildung – Band 1: Inhalte technischer Bildung. Villingen-Schwenningen: Neckar-Verlag.

Höpken, G., Osterkamp, S. & Reich, G. (Hrsg.) (2004). Standards für eine allgemeine technische Bildung – Band 2: Wie man die Qualität technischer Bildung verbessert. Villingen-Schwenningen: Neckar-Verlag.

Interdisziplinäre Arbeitsgruppe BHTW (2006). Kerncurriculum Lernbereich Beruf-Haushalt-Technik-Wirtschaft/Arbeitslehre. Journal of Social Science Education 5(3).

ITEA (International Technology Education Association) (Ed.) (2000). Standards for Technological Literacy – Content for the Study of Technology. First Edition. International Technology Education Association, Reston VA.

ITEA (International Technology Education Association) (Ed.) (2003). Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards. International Technology Education Association, Reston VA

ITEA (International Technology Education Association) (Ed.) (2007). Standards for Technological Literacy – Content for the Study of Technology. Third Edition. International Technology Education Association, Reston VA.

Kauertz, A., Fischer, H. E., Mayer, J., Sumfleth, E. & Walpuski, M. (2010). Standardbezogene Kompetenzmodellierung in den naturwissenschaftlichen Fächern der Sekundarstufe I. Zeitschrift für Didaktik der Naturwissenschaften, 16, S. 135-153.

Kircher, E., Girwidz, R. & Häußler, P. (2009). Physikdidaktik. Theorie und Praxis. 2.Auflage. Berlin: Springer.

Klieme, E., Avenarius, H., Blum, W., Döbrich, P., Gruber, H., Prenzel, M., Reiss, K., Riquarts, K., Rost, J., Tenorth, H.-E. & Vollmer, H. J. (2003). Expertise Zur Entwicklung nationaler Bildungsstandards. Bundesministerium für Bildung und Forschung (BMBF) (Hrsg.).

KMK [Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland] (Hrsg.) (2005a). Bildungsstandards im Fach Biologie für den mittleren Schulabschluss. München: Luchterhand.

KMK [Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland] (Hrsg.) (2005b). Bildungsstandards im Fach Chemie für den mittleren Schulabschluss. München: Luchterhand.

KMK [Sekretariat der Ständigen Konferenz der Kultusminister der Länder der Bundesrepublik Deutschland] (Hrsg.) (2005c). Bildungsstandards im Fach Physik für den mittleren Schulabschluss. München: Luchterhand.

Köller, O. (2008). Bildungsstandards – Verfahren und Kriterien bei der Entwicklung von Messinstrumenten. Zeitschrift für Pädagogik, 54, 163-173.

Krauss, S., Kunter, M., Brunner, M. et al. (2004): COACTIV: Professionswissen von Lehrkräften, kognitiv aktivierender Mathematikunterricht und die Entwicklung von mathematischer Kompetenz. In: J. Doll & M. Prenzel (Hrsg.): Bildungsqualität von Schule: Lehrerprofessionalisierung, Unterrichtsentwicklung und Schülerforderung als Strategien der Qualitätsverbesserung (S. 31-53). Münster: Waxmann.

Labudde, P., Heitzmann, A., Heiniger, P. & Widmer, I. (2005). Dimensionen und Facetten des fächerübergreifenden naturwissenschaftlichen Unterrichts: ein Modell. Zeitschrift für die Didaktik der Naturwissenschaften (ZfDN). Jg. 11, S. 103-115.

Lehrke, M. (1988). Interesse und Desinteresse am naturwissenschaftlich-technischen Unterricht. Kiel: Institut für die Pädagogik der Naturwissenschaften (IPN).

Lind, G. (1996). Physikunterricht unter formaler Bildung. Zeitschrift für die Didaktik der Naturwissenschaften (ZfDN), 2(1). S. 53-68.

Lind, G. (1997). Physikunterricht unter materialer Bildung. Zeitschrift für die Didaktik der Naturwissenschaften (ZfDN), 3(1). S. 3-20.

Meier, B. (2009). Entwicklung und Erprobung von Aufgaben zur technischen Bildung in Qualität Technischer Bildung. In: Theuerkauf, W.E., Meschenmoser, H., Meier, B. & Zöllner, H. (Hrsg.): Qualität Technischer Bildung Kompetenzmodelle und Kompetenzdiagnostik. Berlin: Machmit-Verlag, S. 93-103.

Meschenmoser, H. (2009). Nationale und internationale Kompetenzbereichs- und Kompetenzstufenmodelle zur technischen Allgemeinbildung. In: Theuerkauf, W.E., Meschenmoser, H., Meier, B. & Zöllner, H. (Hrsg.): Qualität Technischer Bildung Kompetenzmodelle und Kompetenzdiagnostik. Berlin: Machmit-Verlag, S. 11-37.

Mokhonko, S., Ştefănică, F. & Nickolaus, R. (2014). NwT-Unterricht: Herausforderungen bei der Einführung eines neuen Faches im Spiegel einer aktuellen Bestandsaufnahme. Journal of Technical Education (JOTED) 2(1), S. 102-128.

Nickolaus, R., Retelsdorf, J., Winther, E. & Köller, O. (Hrsg.) (2013). Mathematisch-naturwissenschaftliche Kompetenzen in der beruflichen Erstausbildung. Zeitschrift für Berufs- und Wirtschaftspädagogik. (ZBW) Beiheft 26.

Nickolaus, R. & Zinn, B. (2013). Positionspapier der Arbeitsgruppe NwT zur Präzisierung und Einlösung der angestrebten Lehrerkompetenzen und Optimierung des Curriculums im Rahmen des Projektes „Ausbildungsqualität durch Kooperation in der Lehramtsausbildung" (AQUA-KOLA). Universität Stuttgart. (unveröffentlicht)

OECD (1999). Measuring Student Knowledge and Skills: A New Framework for Assessment. Paris.

Pfenning, U. & Renn, O. (2012): Internationale MINT-Bildung aus soziologischer Sicht. In: Pfenning, U. & Renn, O. (Hrsg.): Wissenschafts- und Technikbildung auf dem Prüfstand. Zum Fachkräftemangel und zur Attraktivität der MINT-Bildung und -Berufe im europäischen Vergleich. Baden-Baden: Nomos. S. 75-92.

Pfenning, U. & Renn, O. (Hrsg.) (2012). Wissenschafts- und Technikbildung auf dem Prüfstand. Zum Fachkräftemangel und zur Attraktivität der MINT-Bildung und -Berufe im europäischen Vergleich. Baden-Baden: Nomos.

Pfenning, U. (2013). Technikbildung und Technikdidaktik - ein soziologischer Über-, Ein- und Ausblick. Journal of Technical Education (JOTED), 1(1), S.111-131.

Postman, N. (1992). Das Technopol: Die Macht der Technologien und die Entmündigung der Gesellschaft. 4. Aufl. Übersetzung von Kaiser, R., Frankfurt a.M.: Fischer.

Pühler, A., Müller-Röber, B. & Weitze, M.D. (Hrsg.)(2011). Synthetische Biologie – Die Geburt einer neuen Wissenschaft. Berlin/München: Springer.

Rammert, W. (2007).: Technik – Handeln – Wissen. Zu einer pragmatischen Technik- und Sozialtheorie. Wiesbaden: VS Verlag für Sozialwissenschaften.

Ramseier, E., Labudde, P. & Adamina, M (2011). Validierung des Kompetenzmodells HarmoS Naturwissenschaften: Fazite und Deifizite. Zeitschrift für Didaktik der Naturwissenschaften (ZfDN), Jg. 17.

Rehm, M., Bünder,W., Haas, T., Buck, P., Labudde, P., Brovelli, D., Østergaard, E., Rittersbacher, C., Wilhelm, M., Genseberger, R. & Svoboda, G. (2008). Legitimationen und Fundamente eines integrierten Unterrichtsfachs Science. Zeitschrift für die Didaktik der Naturwissenschaften (ZfDN). Jg. 14, S. 99-124.

Ropohl, G. (1971). Thesen zur technologischen Aufklärung. Dortmunder Hefte für Arbeitslehre und Sachunterricht 2(1), S. 19-22.

Ropohl, G. (1976). Technik als Bildungsaufgabe allgemein bildender Schulen. In: Traebert, W. & Spiegel, R. (Hrsg.): Technik als Schulfach. Band 1, Düsseldorf. S. 7-25.

Ropohl, G. (2004). Arbeitslehre und Techniklehre. Philosophische Beiträge zur technologischen Bildung. Berlin: Edition Sigma.

Rossouw, A., Hacker, M. & de Vries, M. J. (2011). Concepts and Contexts in Engineering and Technology Education: An International and Interdisciplinary Delphi Study. International Journal of Technical and Design Education Vol. 21, 409-424.

Roth, H. (1965). Technik als Bildungsaufgabe der Schulen. Hannover: Schroedel Verlag.

Schanz, H. (2003). Ethische Aspekte der Technikdidaktik. In: Bonz, B. & Ott, B. (Hrsg.): Allgemeine Technikdidaktik – Theorieansätze und Praxisbezüge. Hohengehren/ Baltmannsweiler: Schneider Verlag, S. 178-195.

Schecker,H. & Pachmann, I. (2006). Modellierung naturwissenschaftlicher Kompetenz. In: Zeitschrift für Didaktik der Naturwissenschaften (ZfDN) Jg. 12.

Schmayl, W. (2003). Ansätze allgemeinbildenden Technikunterrichts. In: Bonz, B. & Ott, B. (Hrsg.): Allgemeine Technikdidaktik – Theorieansätze und Praxisbezüge. Hohengehren/ Baltmannsweiler: Schneider Verlag, S. 131-147.

Schmayl W. & Wilkening, F. (1995). Technikunterricht. (2. überarbeitete und erweiterte Auflage). Bad Heilbrunn: Klinkhardt.

Schmidt-Atzert, L., Deter, B. & Jaeckel, S. (2004). Prädiktion von Ausbildungserfolg: Allgemeine Intelligenz (g) oder spezifische kognitive Fähigkeiten? Zeitschrift für Personalpsychologie, 3, S. 147-158.

Schöler, W. (1970). Geschichte des naturwissenschaftlichen Unterrichts. Berlin: de Gruyter.

Schudy, J. (Hrsg.) (2001). Arbeitslehre 2001. Bilanzen - Initiativen - Perspektiven, Baltmannsweiler: Schneider Hohengehren.

Schuler, H., Funke, U. & Baron-Boldt, J. (1990). Predictive validity of school grades – A meta-analysis, Applied Psychology: An international review, 39, S. 89-103.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. Harvard Educational Review 57(1), S. 1-21.

Spur, G. (1998). Technologie und Management. Zum Selbstverständnis der Technikwissenschaften. München u.a.: Hanser.

Stemmann, J. & Lang, M. (2014). Theoretische Konzeption einer allgemeinen technischen Problemlösefähigkeit und Möglichkeiten ihrer Diagnose. Journal of Technical Education (JOTED), 2(1), S. 80-101.

Theuerkauf, W.E. (2009). Voraussetzungen zur Erfassung von Kompetenzen und Standards der technischen Bildung in der allgemeinbildenden Schule. In: Theuerkauf, W.E., Meschenmoser, H., Meier, B. & Zöllner, H. (Hrsg.): Qualität Technischer Bildung Kompetenzmodelle und Kompetenzdiagnostik. Berlin: Machmit-Verlag, S. 78-92.

Theuerkauf, W.E., Meschenmoser, H., Meier, B. & Zöllner, H. (Hrsg.)(2009). Qualität Technischer Bildung Kompetenzmodelle und Kompetenzdiagnostik. Berlin: Machmit-Verlag.

Urban-Woldron, H. & Hopf, M. (2012). Entwicklung eines Testinstruments zum Verständnis in der Elektrizitätslehre. Zeitschrift für Didaktik der Naturwissenschaften, Jg. 18, S. 201-227.

VDI - Verein Deutscher Ingenieure (Hrsg.) (2007). Bildungsstandards Technik für den Mittleren Schulabschluss, VDI Verein Deutscher Ingenieure e.V., Düsseldorf.

Wagenschein, M. (1965). Technik und Physikunterricht. Physik-Verstehen als Beistand für die Kinder der technischen Welt. In: Roth, H. (Hrsg.): Technik als Bildungsaufgabe der Schule (S. 305-320). Hannover: Schroedel-Verlag.

Wahner, H.-J. K. (2009). Technische Kompetenzen in der eignungsbasierten Berufsorientierung. In: Theuerkauf, W.E., Meschenmoser, H., Meier, B. & Zöllner, H. (Hrsg.): Qualität Technischer Bildung Kompetenzmodelle und Kompetenzdiagnostik. Berlin: Machmit-Verlag, S. 172-183.

Walberg, H. J. (1991). Improving School Science in advanced and developing countries. Review of Educational Research 61(1), S. 25-69

Walker, F. (2013). Das technische Experiment – Ein Vergleich von Schüler-, Demonstrationsexperiment und dem lesenden Bearbeiten eines Experiments. Journal of Technical Education (JOTED) 1(1), S. 75-97.

Walpuski, M., Kampa, N., Kauertz, A. & Wellnitz, N. (2008). Evaluation der Bildungsstandards in den Naturwissenschaften. Der mathematische und naturwissenschaftliche Unterricht 61, (6) 323–326.

Weinert, F. E. (2001). Vergleichende Leistungsmessung in Schulen – eine umstrittene Selbstverständlichkeit. In: Weinert, F. E. (Hrsg.): Leistungsmessungen in Schulen. (S. 17–31). Weinheim und Basel: Beltz.

Ziefuss, H. (1998). Arbeitslehre - eine Bildungsidee im Wandel: Band 4: Lehrerbildung in der Arbeitslehre. Seelze: Friedrich-Verlag.

Zinn, B. (2008). Physik lernen, um Physik zu lehren – Eine Möglichkeit für interessanteren Physikunterricht. In: Niedderer, H., Fischler, H. & Sumfleth, E. (Hrsg.): Studien zum Physik- und Chemielernen. Band 85. Berlin: Logos.

Zinn, B. (2009). Förderung des Interesses von Erzieherinnen und Erziehern an Naturwissenschaft und Technik im beruflichen Unterricht. Zeitschrift für Berufs- und Wirtschaftspädagogik (ZBW), 105(4), S. 604-621.

Zinn, B. (2013). Überzeugungen zu Wissen und Wissenserwerb von Auszubildenden – Empirische Untersuchungen zu den epistemologischen Überzeugungen von Lernenden. Münster: Waxmann.

Zinn, B. (2015). Naturwissenschaftliche und technische Grundbildung im Kontext beruflicher Bildung. In: Graube, G. & Mammes, I. (Hrsg.): Gesellschaft im Wandel – Interdisziplinäres Denken im natur- und technikwissenschaftlichen Unterricht. Bad Heilbrunn: Klinkhardt (im Druck)

Zinn, B. & Wyrwal, M. (2014). Ein empirisches Erklärungsmodell zum fachspezifischen Wissen von Schülern bei Einmündung in die bautechnische Fachschule. Zeitschrift für Berufs- und Wirtschaftspädagogik (ZBW). (im Druck)

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Zitieren dieses Beitrages: Zinn, B. (2014). Technological literacy – Relevance spectrum, educational standards and research perspectives. Journal of Technical Education (JOTED), Jg. 2 (Heft 2), S. 1-23.