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Technology Development and Technological Education

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Abstract

On a national and international level, technology education is considered to be part of general education. This paper highlights causes and effects, and presents the concepts that are available today for teaching technical subjects. Also discussed is a comprehensive, open approach which covers the essential invariant characteristics of technology education.
Technological change has become an increasingly dynamic and complex process. As a result, a fresh look has to be taken at technology education, which is one of the major aspects of this paper. Only if technology education adequately considers the invariants of technology as well as up-to-date standards of science and technology, students can be enabled to solve technical problems which are of immediate relevance for life.

Technological development

Developments in technology cannot be illustrated without taking a closer look at what is understood by technology. A distinction can be made into the following aspects:

- Technical systems (artefacts and processes)
- Technical action for the construction, use, and dissolution of technical systems
- Knowledge/awareness of the origins, use, and dissolution of technical systems.

Technology and its development are directed at satisfying needs of individuals and society. This implies that humans, with their individual needs and their needs as society, are the origin as well as the aim of technological development.
The very first beginnings of technology are closely related to the evolution of mankind. Man has taken technology from the first primitive stone tools through all its stages to today's high level of sophistication. In view of the complexity of the issue, the question as to what has changed and what has remained the same deserves a closer analysis.

Changes in needs

Let us take a first look at the needs that have to be satisfied. Today, as in the past, technology is expected to satisfy the basic needs of humans, which include lodging, clothing, food, health, etc. However, new and different needs were created as human societies developed, and these needs may by far go beyond the satisfaction of basic needs.

Changes in technical action

The basic principles of technical action (becoming aware of needs; defining tasks; developing ideas; manufacturing, using, and disposing of products), which aims at satisfying needs, has not changed. Technical action involves such activities as innovating, creating, designing/calculating, optimising, producing, analysing, using, experimenting, recycling [1],[2]. Now as before, all technical activities are always complete activities that have to cover the stages informing, planning, implementing and analysing.

Technical action is the tool by means of which humans have successively appropriated nature in the form of technical artefacts. In this way, they have always influenced and changed both nature and the society they lived in, and this has in turn acted back on humankind itself. What has changed is the intensity of the effects of technical action. Today, humankind is in the position to effect not only long-term changes, but also changes that may reach menacing proportions. The tools humans use for their actions have changed, too, and the division of labour has reduced the extent to which individuals participate in these actions to selective sub-actions, as a consequence of which the individuals involved have to be brought together within networks.

Changes in technical processes

When subjecting technical processes to a closer analysis, one will find that the basic structure has again remained unchanged. Operands are transformed in sub-processes/operations from state A to state B through the action of operators. This is true irrespective of whether matter, energy and/or information are transformed. The operators may be machines and humans performing functions or tasks that have been defined for the process in question.

What has changed is the degree of involvement and the role humans play in technical processes. Mechanisation and automation has allowed humans to assign an ever increasing number of tasks to machines, leaving supervising and monitoring functions to themselves. Machines have made it possible to network technical processes that used to be separated and integrate them to highly complex units (e.g. data transfer in the world-wide web). Although closely related to all things that are technical, humans have at the same time moved away from the technical processes, sub-processes and operations as such.

The physical, chemical or biological principles of action determining technical processes have not changed. But today human beings have the ability to avail themselves of an increasing number of natural laws for closely defined purposes, as, for instance, biosensors or laser technology.

Changes in technical artefacts

The pace at which technical artefacts are changing is evident for everybody. This change affects the shape of artefacts, the size (miniaturization: nanotechnology), and the efficiency. For instance, cars and computers that are in common use today differ in a number of ways from earlier generations, while the basic functions are still the same. A fork or a knife has not seen any change in their basic functions, nor has the basic function of a car, which is to transport an object from A to B, experienced any change. Only new functions have been added to the list. Changes that have taken place concern the degree of cross linking and complexity of technical artefacts. An example that can be mentioned in this context is the intelligent house. The ways in which technical artefacts are produced have undergone changes, too. The use of heavy-duty materials, the quality of the products, and the automation of the manufacturing process, which allows large quantities to be produced at a constant quality, are indicators of the high level of sophistication.

Changes in knowledge

The half-life of technical knowledge is decreasing in the same manner as this is experienced for other disciplines. Technical know-how is exploding as intervals between inventions, discoveries and developments are becoming shorter and shorter. During the early stages of technical development, knowledge was normally generated from experience and was handed down to the next generation as empirical knowledge. This was also true for the handicraft/practical phases of the Middle Ages.

The scientification of technical methods is a relatively recent phenomenon, which employs mathematics as well as the natural sciences as methods to generate scientific insights. The process of scientification eventually produced such specific disciplines as information and communication technology, as well as biotechnology and genetic engineering, environmental technology, energy technology, material technology, aviation and space technology, traffic engineering, micro technology, laser and plasma technology, medical engineering and building engineering, which may affect the reality of life of each individual. It is worth noting at this point that there is an increasingly higher level of interconnection, both between the different technical sciences, and between the technical sciences and the natural sciences and mathematics (e.g. mechatronics, biotechnology). Information technology, in addition, plays an important role as a basic technology for all technical sciences.

But also the way of how knowledge (or rather information) is passed on has undergone substantial change, as oral tradition, and later hand-written and printed documentation, was replaced until information technology became the major instrument for passing on knowledge. This technology is now providing almost global access to information, irrespective of place and time.

Changes in responsibility

In the course of its development, technology has allowed both people and peoples to move closer together and to overcome dimensions and distances. At the same time, mankind is now in a position to put its livelihood at risk. Even without waging war, which would certainly be tantamount to absolute destruction, we can do a lot of damage to our basis for living, merely as a result of technical action – if it takes place without being aware of, or considering, the principles of interaction.

It follows from the above that for today's humankind it is important to understand the implications of technology. This will allow us to develop, and make use of, new technical systems in a way that reduces consequences and risks to a manageable level. Only those who understand how technology affects all walks of life, and that, by using technology, human beings act back on themselves, can translate knowledge into responsible action.

Technology education

Significance of technology education

According to Schlaffke, general education should be seen as a foundation which "is ready to support a complex building of education – with an increasing number of storeys and corridors". General education should provide global knowledge, and the ability to think along structural, procedural, or systematic lines, but also standards of value, which are all combined to form one complete concept [3]. Education is more than knowledge, which, on the face of it, can be utilized as a key to the job market and a means of social balance. Education has to prepare for a "life in freedom and self-determination". It has to enable individuals to cope in an "open and highly complex world offering new kinds of freedom", without allowing themselves to be drowned in a "maze of facts and events". Education must not remain limited to imparting knowledge and functional abilities. To allow human beings to develop their personality, education also means imparting values and social competences. On the other hand, school education must not remain separate from the realities of life. Schools have to arouse and encourage interest and inclination, no matter whether this means developing practical or theoretical talents. They have to counteract premature specialisation, offer a wide range of subjects, and thus impart a broad basic knowledge, without heeding later professional carriers [4].

If we endorse the conception according to which school education should enable individuals to cope in a highly complex world and to understand the significance of technology for the reality of life of individuals, as well as its significance as a cultural heritage, technology education undoubtedly has to be seen as being part of general education.

Education comprises three basic components. These are the process of imparting knowledge as an informational component, the process of learning to learn as a didactical component, and the process of arousing interest as a motivational component. Against the background of a rapidly changing technical world, the question is what technical knowledge should be imparted, what share the informational component of technology education should have. "As technical systems are becoming more complex [...] and as we are abandoning the utopian idea of understanding technology, the didactical and motivational components of technology education are gaining significance. Today, education is, therefore, above all the ability of learning how to learn. It is not the product-, object-, or formula-based learning which gives access to understanding, but the process- and phenomena-related learning, and the ability to apply the acquired knowledge and translate it to other fields" [5].

If "understanding technology" was referred to as utopian above, this primarily means the impossibility to understand technology as a complex phenomenon with all its facets. Technology education should rather aim at presenting technology within a context by relating to examples, and thus illustrate underlying structures and functions. The insights thus gained can then be raised to a meta level which offers the possibility of transferring acquired knowledge. Ideal tools for his purpose are system theoretical models [6], [7], [8], [9].

The intention of technology education is to develop a competence to act in every student, irrespective of any later professional carriers or any personal inclinations or preferences. This competence is seen as the disposition of the individual to successfully solve problems in a given technical situation.

Technology education should aim at enabling students to

- be part of a process in which a world undergoing technical change has to be given shape
- be capable of responsible technical action, which gives due regard to the interrelationship between humans, nature, technology and society
- cope with technical/practical requirements encountered in our daily lives and on the job
- understand the principles of technical systems

- be able to use their basic technical understanding to decide in favour of a technical profession.

Development of technology education

Developments that have taken place in technological fields have also had their effects on technology education, but other factors have also plaid their role. These include the economic and political situation, the pedagogical mainstreams, and the significance that is attached to education. Some of the main concepts of technology education, which may still be relevance today, are outlined below [10], [11].

Manual skills

Manual skills with their practical orientation started to be taught as a school subject in Finland, Sweden and Denmark at the end of the 19th and beginning of the 20th century. But the Vienna World Fair in 1873 and the Philadelphia Centennial Exhibition in 1876 made it quite clear that the quality standard of industrially produced consumer durables was poor, which was attributed to inadequate practical handicraft skills in handling machinery and tools. Manual skills as a subject not only aimed at improving the skill as such, but also at supplementing the purely theoretical subjects and thus striking a balance between physical work and mental activities as one means of encouraging the full development of the student, which was one of the basic pedagogical requirements. The skills taught concentrated on traditional manufacturing methods and the systematic development of the ability to handle such materials as paper, cardboard, timber, and metal. The subject was widely introduced in many countries, including the United States, Russia, Romania, France, England, Hungary, Austria, and Belgium.

Polytechnics

The polytechnic approach dates back to the first polytechnic schools in Paris in 1794, which was the time of industrial schools. Marx started from the ideas and principles of this " Ecole polytechnique" to develop a concept of education, in which brainwork, physical work, and a polytechnic education combined to form one unit. With this concept, the polytechnic part covered the general scientific principles of all production processes and also the practical use and handling of the elementary instruments needed to perform the production process. The concept implied a fundamental expansion of earlier practical handicraft approaches to arrive at a technical and economic education, which combines theoretical as well as practical elements of work.

This educational concept could not be implemented until after the first socialist countries came into being, i.e. after the fundamental changes had taken place in the 20th century in production and ownership structures. Politically, the polytechnic approach aimed at the education of socialist personalities. What its proponents had in mind was a technical and economic education that was to encourage people to take their share and responsibility in shaping society.

The curricular program of polytechnic education has concentrated on production processes and engineering sciences. A special feature of these schools was that, starting with the primary to the school leaving levels, the subjects were based on each other, that a shift took place from school as a place of learning to a more practical environment (workshops, polytechnic cabinets, industrial workshops, production departments, development departments). This was accompanied by a change from supervised practical activities to practical scientific work. Despite its distinct political orientation, the significance of polytechnic education has to be seen in the close links between education and the technical/work environment, in the uniform technical education it offered, in the fact that it provided a defined transition to vocational training or university education, as well as in a consistently developed and coordinated concept and teaching materials.

Work orientation

Work orientation means to focus on the actual work environment and the interrelationship between humans, work, technology and economy. Needs are assumed to be a starting point, and work is seen as a tool that can be used to satisfy these needs. From this follows that technology is always viewed in its relationship to work and its influence on humans. The aim of this approach is to convey insights into work processes, to develop a positive attitude to work/technology, and to help prepare for an active professional life [12]. In curricular respects, the approach starts from the model of the business process and integrates the field's work/profession, home economics, technology and economy. The work orientation can be seen as a more advanced level of manual skills teaching, with its development from a handicraft to an industrial approach. In countries, which do not know the German dual vocational training model, e.g. China and the United States, this concept is of special significance. This approach is also where the German "Arbeitslehre" would have to be located.

General technology – systems theory

System theoretical considerations relate to thinking in terms of systems, which is typical of humans and takes us back to the ancient world. This way of thinking means to comprehend things within global contexts. More specifically it means that all technical systems are regarded from the point of view of material, energy and information and their modifications. Originally, this approach was a fairly strict technical approach relating to the processes and artefacts involved. It has now been expanded to include socio-technical aspects.

The significance of this approach, i.e. thinking in terms of systems, has to be seen in the fact that it helps to think in terms of models and thus has a propaedeutical scientific element. It aims at conveying engineering subjects and methods and is to prepare for engineering courses at university. In the US, and also at the secondary school level (Senior High School) in the federal states of Brandenburg and North Rhine-Westphalia, this approach has, for instance, been integrated into the curriculum (Technical aspects are linked with mathematical and scientific elements, as well as elements of a mathematical-scientific-technical nature).

Science and technology

This approach is rooted in the natural sciences and the engineering sciences, as well as their specific methods. Solutions may be sought in either scientific or technical options. The underlying aim is to develop cognitive skills (thinking in terms of systems), to develop research and planning skills (planning of experiments and processes), and to develop practical skills (performing measurements, producing electric circuits). This approach is valid for elementary schools, as well as for junior high schools or senior high schools. In teaching the subject, scientific and technical elements are linked. This approach is actually used as part of the subject Science and Technology in the United States and in Israel. But in Germany, too, similar methods are used for illustrating phenomena in the natural sciences, with concrete technical applications.

Design and technology

When technology education focuses on design as part of its teachings, this is because needs and desires are at the bottom of any development, and for developments to take place, there have to be inventions. For this reason, this approach is directed at developing innovative skills and creativity, or in other words, at turning students into creative inventors and problem solvers [13].
The curricular programme concentrates on inventing, producing and evaluating products. Central elements are the processes of invention and design, while production is of lesser significance. This approach is implemented in England as well as Australia as part of the subject Design and Technology.

Implementing Technology Education at schools

The concepts for technology education as outlined above incorporate different kinds of technical action, which may also vary as to its emphasis. Concepts for technology education have changed along with developments that have taken place in the technical sector and along with what were seen to be educational requirements.

When considering the complexity of today's technical systems, technical action may serve as a key that gives access to technology with its basic structures and functions, and the aspects linking it to humans, nature and society. This relationship for technical action is also found in international concepts, where reference may be made to such fields as building and accommodation, work and production, supply and disposal, information and communication, food and health, clothing, playing and learning, which relate to the students' immediate life experience.

In dealing with the above fields of action, the attention should be directed at such guiding principles as the preservation of the environment, careful use of resources, and protection of the human dignity and the cultural heritage [14]. Depending on the cultural, political or economic situation, in which action has to be taken, different fields of action may be attributed special importance.

As a general conclusion, technology education can be said to be integrated into school curricula in the following way:

- Primary level: phenomenon-based work
- Secondary level I: theoretical and practical work
- Secondary level II: propaedeutical scientific work

For technology teaching at what are seen to be open schools, external partners are increasingly integrated into the programme. These may be partners in industry, handicraft businesses, the service industry, or (educational) institutions, who may have the function of initiating tasks or offering room for action, or they may provide experts or equipment, as well as the necessary professional orientation. At the first level of secondary school education, suitable partners would, for instance, be the production sector of small- or medium-sized businesses or handicraft businesses, while for the advanced secondary school level this could be planning and research in industry or at universities. Positive experience with this kind of co-operation has already been made (MINT, TheoProx, Step-In, etc.).

Conclusion

Interest in technical matters can be aroused when the subject is introduced in a playful manner at an early stage, and this interest can be consolidated when technology forms part of the curriculum from the primary level to the school leaving age. Technical tasks that combine theory and practice can, in addition, be motivating and have a reinforcing function, because the result of the learning process is a real and concrete result. Developments in the technological field require everybody to be permanently involved in the subject, so that the function of technology education is to prepare for lifelong learning.

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Biography

WALTER E. THEUERKAUF was head of the Department of Technical Education and Information Technology at the Technical University of Braunschweig. After graduate education he received his doctorate in energy technology at the University of Hannover/Clausthal in Germany. After significant industrial experience he was appointed as professor for technical education. His teaching and research focus is on technology education for general education and additionally on systemic learning in occupational education. He is the Präsident of the "European Society for Technology Education (EGTB)" and Viceprasident of the World Council of Associations of Technology Education (WOCATE)"