An integrated concept for Technology Education in public schools

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ABSTRACT

The curricular concept that serves for the training of aspirants for teaching posts was developed in the framework of a project that was supported by the European Union. The module “Teaching Technology”, that is described here, deals with the contents of modules, which concentrate on the specialist issues. However, also an independent module tries to embrace the recent state of affairs in terms of technology education against its international background. Thus, it is meant to represent the basis for a concept that is in line with European standards of the professional qualification of aspirants for teaching posts regarding technology education.

1. INTRODUCTION

This didactic concept describes the present state and the future perspective of technology education. It is based on the acquisition of data on national and international implementation of technology education, which included the evaluation of national and international conferences and publications, putting special emphasis on the past and present developments in technology education in Europe and the Americas (Petrina 2007).

The educational concept does not exclusively refer to the school subject of techniques, it also deals with the technology education that should be conveyed at secondary schools of general education. The exact subject and the sets of subjects in which teachers convey technology education depends primarily on the respective academic conditions. They have to meet the professional and didactic requirements of this field of expertise. However, technology education should always be the starting point in this matter. Engineering science and technology form the specialist basis of technology education. In this context, it has to be stated that technology and its implications can also be observed and evaluated from the viewpoint of other branches of study, e.g. technology as an element in political and social problems. This sets the subject into a different light, and shows the subject in a perspective that is often over-looked.

The educational and didactic criteria of technology education refer to a methodical and functional frame that tries to offer solutions that allow for global aspects. Apart from basic aspects, separate showcase issues regarding education practice are represented. It must be noted that technology underlies constant changes, which in turn has consequences on technology education. This is a fact that holds true for both general education and professional training. This is why the frame of key technologies, which are characterized by innovation and further development, are no absolute term for didactic considerations. A concept that claims to convey methods for the implementation of technical contents at secondary schools must consider the didactic and scientific aspects of the matter. This summary of the curricular conception of the module and of the basics of educational implementation can only go into the essential and innovative focus.

2. PROCESS ORIENTATION

Techniques is often described and dealt with on the basis of systems theory. The reason for applying cybernetic models is the fact that nearly every scientific field uses orientation with the means of systems for the description of situations and behavioural patterns (Theuerkauf, 2007). The systems are regarded as closed though they interact openly with their environment; however, they are basically characterized by the processes within them.

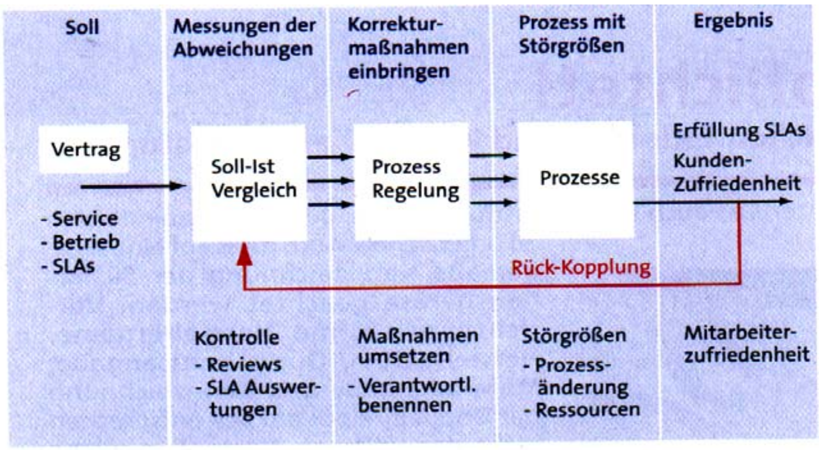

Fig. 1: Basic structure of processes: circular structure.

If the focus of a curricular approach lies on the technical considerations and actions, the starting point should be the respective process that is incorporated into the system with its limitations. The understanding of the effects that technology brings about cannot be measured with the systems alone; there has to be an integration of the technical systems into active processes. The universal validity of this is pinpointed in figure 1, which shows a non-technical process. In respect of the universal validity, it has to be added that processes are usually underlie automatic controls, in which microprocessors plays an important part. Along with the digitalization, there is also computerization of all processes, which represents a parameter of technical change. Computer science is therefore to be seen as a transsectoral science.

The process should hence be the basis for transsectoral examinations, as it al-ways depicts the respective technical, economic, medical actions for all fields of expertise. Fig. 1 shows the basic structure of a process. It depicts a defined or plausible succession of states in chronological order that is dependent on the preconditions and external influences. The course of the process can be predefined, or it can also be influenced.

Food production, as e.g. the production of bread or beer may serve as an ex-ample. The characteristic feature of these two processes is the fact that biological and chemical processes – non-technical processes that is – determine the respective food production with their operations on the various operational levels. In this case, people – the baker or brewer – and the technical system have an impact on the process.

The technical system of the process executes the mixing of the baking ingredients as a procedural operation during which in the mixing system (the mixer), an energy transformation process takes place. The transformation of electric energy into mechanic energy and its pipelining to the motor of the stirring device characterize it. An examination of this process opens a more generalised perspective since operations go hand in hand with transformations. These transformations are carried out in technical processes by means of special technologies, as they can be observed in process engineering or product engineering (according to the norm DIN 8580 of the German Institute for Standardization). The active principles of the respective technologies are based on a scientific phenomenon, e.g. the laser that is used in welding.

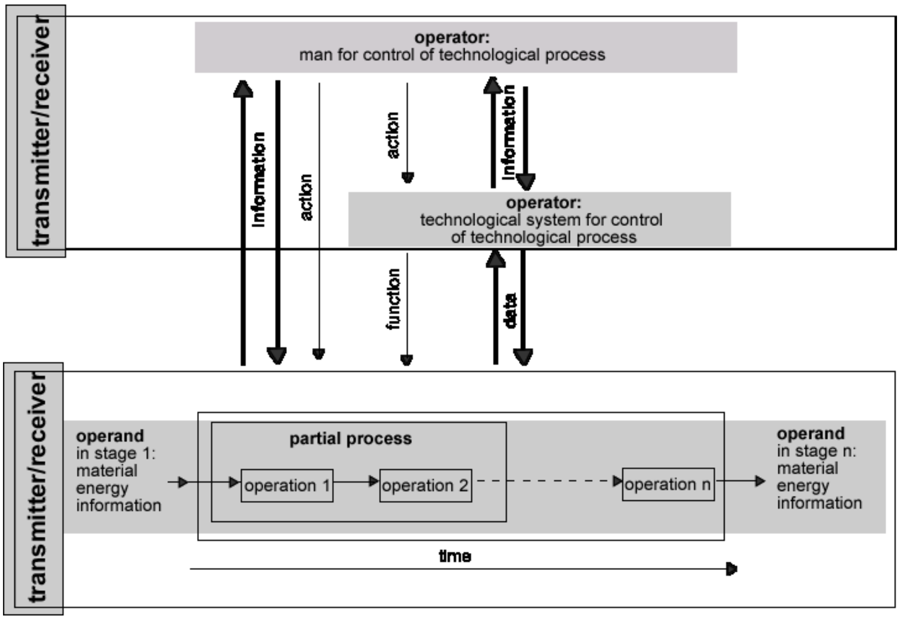

Fig. 2: General process according to Hubka (adapted by Graube/Theuerkauf 2003)

Water preparation was chosen here because it unites the features of many other examples. The whole process is shown in a technology schema in the below figure.

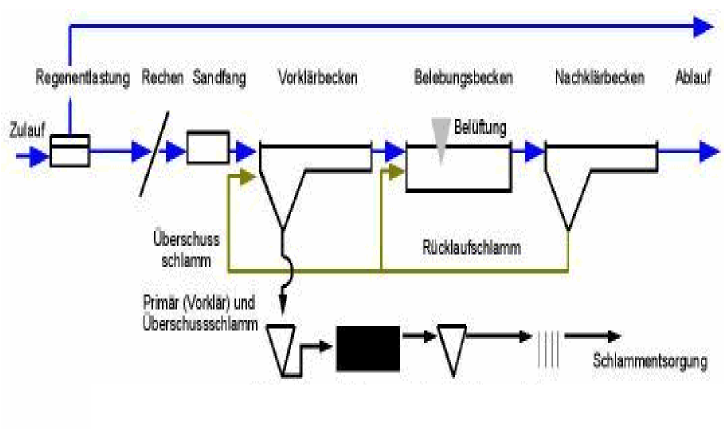

Fig. 3: Technological scheme of water preparation

The technological scheme shows the individual sub-processes, namely mechanical, chemical and biological processes that work together in an overall process of water preparation. This process serves two purposes: first, to remove foreign sub-stances (sterilization, demineralization, etc.), and second, to add substances that enhance the quality of the water for the consumer (e.g. regulation of the pH-value). This example discloses the need for cooperation between individual fields of expertise in order to solve problems that occur in the development and design.

Secondary schools have to contribute to this in two ways. Firstly, they have taught their students the basic skills necessary to meet the demands of the world of work. Second, they have to provide them with an overview on professional requirements (which is a task for each subject at school). For wrong decisions concerning the choice of a career cannot only have serious consequences for the personality, they can also cause economic damage.

Thus, the overview should concentrate on key qualifications since these constitute a central area of human and educational development in the sense that they are understood as personal, intellectual, or social skills. They provide students with the competences necessary to meet the demands of the professional world. These competences correlate with the demands of industry and trade (as specified in SCAN 1992). Both expect secondary schools to impart these skills, which could be generally subsumed as follows:

- the ability to organise and carry out a task
- the ability to co-operate and communicate
- the ability to apply working and learning techniques
- the ability to work independently
- the ability to handle stress

Since technology education is linked in principle to the qualitative requirements of technological professions, an operation-centred technology education can make an important contribution on the theoretical as well as on the practical level.

3. INTEGRATIVE CONCEPT OF TECHNOLOGY EDUCATION

An analysis of the current international technology education provides the basis for the global perspective on technology education, which should cover the following criteria:

- it has to consider the scientific level of technology in industrialised as well as in developing countries
- it has to enable the students to understand technological work, i.e., enable them to understand how technological concepts and processes function and how to handle them adequately in different situations
- concerning basic needs, it should relate the learning contents to the national and international key problems
- it should be linked interdisciplinary to other technological and non-technological disciplines in order to enable the students to comprehend technology as part of problems that should also be regarded from e.g. a political point of view and be accordingly evaluated
- it should impart basic technological skills and proficiencies concerning process and product engineering
- it should enable the students to acquire the general skills they need for working and

studying; it should particularly provide an overview on professions in science and technology and their respective requirements

- it should consider the educational impact of technology education on the students' self-development: learning to deal with technology and technological structuring from the perspective of an integrative education (uniting mind, heart, and hands)
- it should treat technology also with regard to its cultural dimension, i.e., as a cultural heritage seen from its historical, current, and future aspects (Technosophie, see Spur 1998)

This integrative concept of technology education covers a wide range of aspects. Since it relates to technology education both on a national and on an international level, the global concept should take into account as many different aspects of techno-logy education as possible. This also means to ensure that the specific needs of the different countries are taken into account as well. It goes without saying that basic needs are of importance in every country; they are, however, cultural and regional aspects to be taken into account that are marked by the historical, industrial, or agrarian development of the respective region. Key problems of daily life like globalisation, unemployment, pollution etc. have also been taken into account. Basic needs are defined as follows:

- space for living: housing and living
- work and productivity
- energy as a resource for life
- alimentation and health-care

These needs are the basis of human life, no matter in which country or which continent, and since technology has an impact on all of these needs, it is important to deal with them as a central topic. The different aspects do not, however, relate to a certain level of education at schools, but provide an orientation for all levels of education at schools, in the sense that they provide a spiral pattern for the syllabus. They are starting points for the practical examples of the module, which have been developed and tested in teaching practise.

4. COMPETENCES AND STANDARDS OF TECHNOLOGY EDUCATION

A résumé of the various approaches to and fields of technology education will show that there are considerable differences between them, although these differences may not be discernible at first sight. The approaches vary, however, in relation to their perspective on technology; in other words, there are differences according to the field of technology education be it engineering sciences or be it pedagogy, where technological contents are seen as mere vehicles when pursuing the educational aims of developing the personality. As far as natural sciences are concerned, technological artifacts or systems are seen as the application of the respective laws and phenomena of natural science. Then there is technology education at school, where it forms part of such different subjects as e.g. natural sciences, economics, or political science and education. All this shows that technology education has an inter disciplinary character; a property it shares with information technology – both represent a scientific quality that links, and is common to, otherwise vastly different subjects.

Whatever the educational situation and purposes may be, it is import to define which competences/skills are to be imparted to the students, which technical con-tents they are to be taught, and which standards are set as aims to them. This is of advantage and thus of special importance with regard to a possible international comparability of technological education.

Establishing internationally agreed on standards, competences/skills could help technology education to gain a status comparable to the status the natural sciences already enjoy on international level. It is thus obvious that natural sciences provide an example and adequate frame for defining the competences/skills to be obtained by technology education.

These competences/skills are based on those already defined in the Pisa studies. Table 1 shows four fields that have been defined for technology education in analogy to those defined for natural sciences:

Table 1: competences of technology education (adapted after Oberliesen a.o. 2007)

Competences	Description of necessary contents/ abilities
► to analyse technical processes and systems	Systematic classification and description of technical processes and systems on the field of mass-, heat-, and information transfer ; description of the way they form technological structures
► to apply technology	Structural understanding of how to apply technology; basic technical skills, both theoretically and practically
► to communicate technical facts	Basic knowledge of technical terms and technical language; basic knowledge of the documentation of technical facts
► to evaluate technical processes and systems	Evaluate technology by taking into account how technology, men, nature, and society interact with each other

The next step to take is to transform the competences into standards that come up to the level that is the basis for an international evaluation according to the standards defined by Pisa. Table 2 shows twelve standards that will provide schools with starting points for a more profound occupation with the standards' respective contents.

Table 2: Standards of technology education (adapted after Oberliesen a.o. 2007)

No.	Description
1	**Product development:** • explain, apply, and give reasons for the technological structuring of product development
2	**Basis methods of approaching technological problems:** • description of technological problems • development and description of possible solutions • knowledge and application of the necessary mathematical methods of calculation • comparative evaluation of possible solutions • realization of solutions

3	**Practical basic skills:** • explain and practice the appropriate, safe, and environmentally sound handling of selected technical materials, tools, appliances, and machines
4	**Methods of communicating technology:** • use of multimedia means and knowledge of current technical norms • ability to interpret technical documentations • adequate description of technological facts with regard to the intended addressee
5	**Processing and useful properties:** • describe and compare the processing and useful properties of selected technical materials • give reasons for the purposeful use of these materials
6	**Systems of mass-, heat-, and information transfer:** • explain the technical processes involved and give reasons for their purpose (transport, conversion, storage)
7	**Structure of mass-, heat-, and information transfer systems:** • explain and apply systems and functions of such systems
8	**Historical and current developments of technological systems:** • analyze and evaluate such systems concerning their principles, linking, automation, and organizational forms
9	**Decision-making:** • analyze, explain, and evaluate the decision on technological systems and processes with regard to technical, economic, ecological, and social aspects (like functionality, cost and benefit, economic use of resources, safety, ergonomics, manageability, design, maintenance, susceptance to failure)
10	**Quality assessment:** • assess the quality of one owns work and develop possible ways of quality improvement
11	**Correlation between technology and living:** • understand and evaluate from different perspectives the correlation between technological change and the changes in social and natural contexts
12	**Inter-disciplinarity:** • comprehend the relations and correlations between mathematics, natural science, informatics, and technology and be able to apply them when solving technological problems

These standards correlate largely with the standards in other European countries as well as with US-standards for technology education (a.o. Technology Literacy, standards of The Association of German Engineers VDI). An implementation of these competences and standards of technological education into the schools' curricula and syllabi would provide technology education with a global basis. Moreover, it would allow to achieve the desired international comparability of the students' performance which has already been realized in other subjects like e.g. the natural sciences.

Apart from imparting the necessary technological basic knowledge, i.e., imparting basic knowledge of the basic technological systems and processes, i is indispensable for secondary schools to orient on the basic needs that are in particular related to the key problems of the global structural changes. These problems include the acceleration of industrialization, the rapid growth of the global population, the global underfeeding, the exploitation of the reserves of raw materials, and the ecological destruction (see Opaschowski 2007). An editorial in the professional journal "Elektrotechnische Zeitung" (ETZ) gives detailed reasoning for this orientation on the key problems and the key technologies related to them, further relating to the particular effects both automation and communication technologies have on those.

5. THEORIES AND METHODS TO MAKE TECHNOLOGY ACCESSIBLE

Technological thinking and actions have to be derived from practice and exercise, in other words, from solving and thus handling technological problems. This is the core of technological thinking and actions, and it has two main aspects. Firstly, the specific technical actions with regard to the technological task; and second, the social and human esteem that the result of the technical actions receives.

To act means an intentional behavior with the purpose to reach a set aim. It is as a rule linked to a change in the original state, and it is linked to particular aims, which have to serve a particular purpose. Such actions can succeed or fail. Non-repetitive actions have always an aspect of uncertainty since possible obstacles may lead to failure. However, this is an aspect characteristic for each and any action.

Technical actions are different from artistic or economic actions. Current scientific literature knows various definitions of technical actions, which shall be sketched briefly in the passage below:

- Technical actions can be defined with regard to the relation of purpose and means. This notion goes back to Hegel; it focuses on the purpose and the means of an action. In other words, it characterizes technical actions as instrumental and purposeful. This definition may be of use when dealing with questions of cultural philosophy, but it does not provide an adequate description of technical actions
- Technical actions can be seen as the handling of technological artifacts and systems, which means to focus only on the use of technology and per-haps on its effects within society. This approach neglects the production process and its creativity, which is characterized in particular by its contribution to the shaping of the world by technology. However, the technological skills and knowledge that are essential to this creative aspect of technological actions does not come to mind when using, for instance, a kitchen appliance
- Especially from the perspective of the natural sciences, technical actions are defined as the practical application of scientific knowledge. This implies that innovative concepts for technological systems and processes are more or less by-products of scientific research and findings. There are many examples for this notion, e.g., the development of the transistor or the laser. Yet it does not reflect reality. On the other hand, solving a technological problem does normally include to look for possible contributions of the natural sciences

- Technical actions have to be seen in relation to the persons who are technologically productive and make use of technology. This definition includes engineers and skilled engineering workers who are working in research, production, service, and maintenance; it also includes the people who use technology
- Furthermore, technical actions happen on all levels of the production process. This means that the production cycle and the related technical processes may serve as a didactic orientation for technology education since almost all technical actions can be derived from the phases of the production process. Moreover, they are closely linked to technological professions and qualifications.

Manufacturing products means to go through the different phases of the production cycle from which then the specific technical actions can be derived. Analyzing this, the following parameters for technical actions may be distinguished:

- Innovative/creative actions
- Constructive/interpretative actions
- Defining/manufacturing-related actions
- Logistic/distributive actions
- Evaluative/experimental actions
- Maintaining/repairing actions
- ecological/sustainable actions

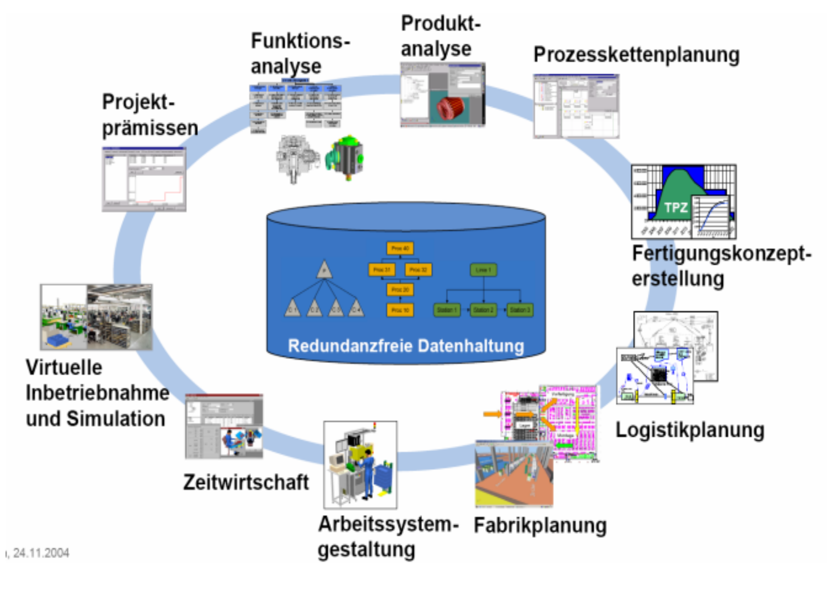

Fig. 4: Production cycle (Karras 2005)

Generally, spoken, technical actions are an iterative and optimizing process that is repeated several times and that is valid for all phases of the production process. The so-called theory of psychical regulation of actions serves as a basis to locate technological actions theoretically and shows how to organize technical actions both in theory and in practice.

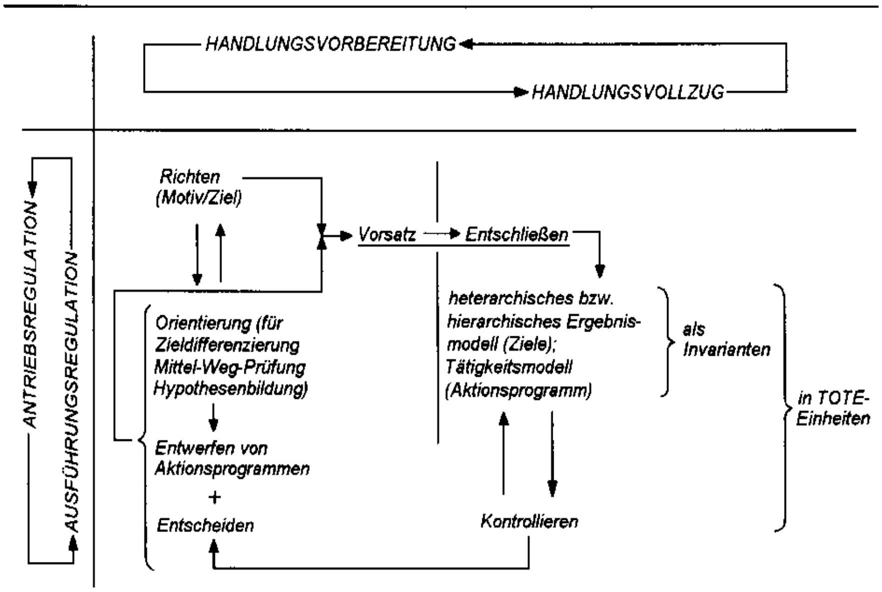

Fig. 5: Schematic representation of psychical regulation (Hacker 2005)

Coming back to the opening statement of the chapter, it becomes clear that the learning processes in technology education have to include complete actions. This has the additional advantage that the correlations between the technical actions and the respective process at work become visible which provides a basis for both practical lessons and job orientation.

6. LEARNING ARRANGEMENTS

One of the aims of education is to enable students to handle the tasks and problems of their future professions. It is thus indispensable to offer them real-life tasks and problems in class (see Mandl 1997). Cognitivist and constructivist concepts provide the theoretical basis for a learning situation that enables the students to reach the above-defined aim:

- Situative learning with tasks and problems taken from real life – Basis of this approach is a task/problem whose “realness” makes it attractive in itself for the students to handle/solve it. Furthermore, the learning facilities should provide the students with an environment as realistic as possible to prepare them for coming situations in their professional lives.
- Learning in multiple contexts and from multiple perspectives - It is important that the students shall develop the ability to transfer the contents they have learned to other contexts, i.e., be able to apply the contents independently from the context within which they first have learned them. This is best achieved by offering the same learning contents in different contexts and by additionally studying them from different perspectives. The learning situation should thus enable the students to acquire technological knowledge and skills in different situations in order to become competent in transferring learned contents

To meet these requirements, learning locations outside the secondary schools play a particular role. Such locations could e.g. be companies, but also vocational schools deserve to be mentioned since more and more secondary schools form partnerships with vocational schools and thus new forms of learning are necessary.

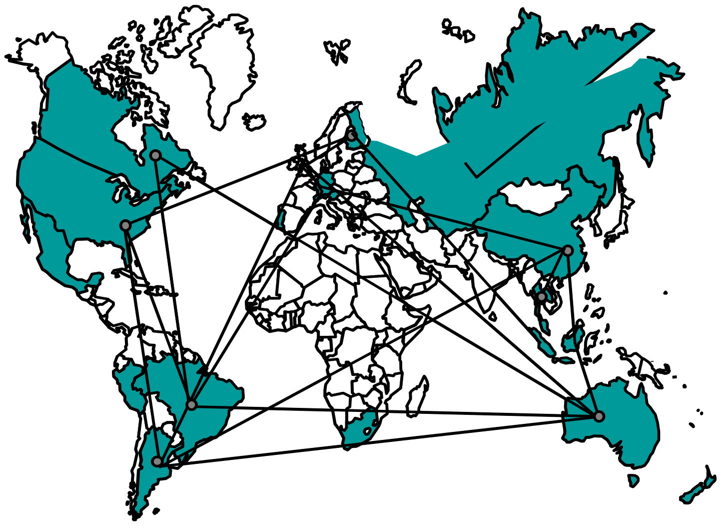

Fig. 6: Global learning network

The exchange between learners at secondary schools and learners at university increases in quantity and value in our globalizing world. To further extend these contacts on national and international level, the method of collaborative learning offers itself. This groundbreaking approach shall here be illustrated by briefly describing its appliance to a project of technology education. First, a learning community is installed that consists of interested learners who learn at different learning locations. When a common project is agreed on, e.g. constructing an electronical circuit for an anti-theft system, the project is carried out following the usual procedure. The only difference to the normal course of action is that the participants' verbal and written communication takes place via internet. It is important that the project management organizes this; the necessary assistance and technical advice may come from the teachers or also from external specialists.

7. FINAL REMARKS

The module "Technology Education" as depicted here in this article goes beyond the usual criteria for structuring classes in technology education. Finally, it shall be pointed out that the module contains exercises that link the didactic module to the technical ones by imbedding the first into the curricula of the latter.

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