Technology 15+. Integration of technology in science subjects in The Netherlands

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Abstract

This presentation draws from experiences obtained from the project 'Technology 15+'. In 1997 the Dutch government decided to integrate aspects of technology in the science subjects of the upper level secondary education. Under the authority of the Ministry of Education the project group "Technology 15+" developed a didactical framework and curriculum materials for the integration of technology and design activities in science subjects. The project group "Technology 15+" is a co-operation between educational institutes, teacher training centres and the National Institute for Curriculum Development. Where initially the attention was directed towards teaching contents and curriculum development, now the focus is on a wide and durable implementation at all secondary schools. In co-operation with technical colleges, universities, local industry and secondary schools we organise regional networks for supporting design activities in (and outside!) the schools. This support can have different dimensions, e.g. in-service training for science teachers, technical students coaching pupils working at design activities, pupils from secondary schools doing their practical work at the institutes, Internet support and visits to industry, etc. In my presentation I will focus on issues identified within this project and how they have been resolved.

Keywords: science, technology, upper level secondary, design process, creative thinking

Introduction

In this paper I will explore some issues connected with the development of design modules in the science curriculum. The backgrounds of the project Technology 15+ were recently presented in London (de Beurs, 2000).

Technology education in The Netherlands

In the Netherlands technology was introduced in general education in 1993 as a compulsory subject for all pupils in lower secondary education (age 12–14). Basic curriculum elements are 'technology and society', 'handling products of technology' and 'technological problem solving'.

In primary schools technology is integrated in existing subjects like craft and science with an orientation on designing, making and investigating products of technology.

Until recently in the upper level curriculum of general education (age 15–18) a technology component was missing: technology for 15+.

The project Technology 15+

Technology 15+ is a co-operation between several educational institutes:

- AMSTEL Institute, University of Amsterdam,
- National Institute for Curriculum Development (SLO)
- schools (60), technical colleges (5) and universities (4) organised in regional networks (4).

The aim of the project is the development and implementation of a technology curriculum in the upper level of secondary education. Connected with the intended revision of the upper level curriculum in 1997 the question of how to include a technology component in upper level secondary education was a point of discussion from 1993. Should it be a separate subject or integrated in existing subjects?

In 1995 it was decided that technology should be integrated in the existing science subjects. The option for a separate subject was rejected on the argument that fragmentation of the curriculum into many subjects should be avoided. In the next two years the examination programs for all subjects in the upper level curriculum were adapted. Technology was integrated in the programs for science subjects by defining a few technology domains in each subject and by admitting design skills to the general list of acquirable skills. As a part of the obligatory practical work in the last two years of science education (40–80 hour) pupils are allowed to make a choice between a research project or a design project. The new examination programs were operative from August 1999.

On an assignment of the Ministry of Education the project group T15+ started in March 1997 with the development of design modules for use in the subjects biology, physics and chemistry.

Figure 1.

From February 2000, the project gained momentum with funding from the Ministries of Education, Economy and Social Affairs. Where initially the attention was directed towards curriculum development, from that moment the focus became on a wide and durable implementation at all secondary schools. In co-operation with technical colleges, universities, local industry and secondary schools four regional networks are established to support the design activities in (and outside!) the schools.

Changes in science education

For a better understanding of the latitude for technology activities within science we need to say something about recent changes in science education. Science is suffering from the problem that too many pupils are considering science subjects as 'difficult', 'theoretical' and 'boring' with no clear connections to every day world. This is particularly the case for physics and chemistry and to a lesser degree for biology.

One of the proposed answers to this problem was 'applied science'. Under the influence of the 'applied science movement' more context was added to the science curriculum. In Holland the applied science movement had its origin in the 70s and is still influential. Besides the motivational aspects, applied science was considered necessary for a better understanding of the school theory. The improved understanding is a result of the process of 'constructing' knowledge from meaningful science activities and applying theory in different contexts.

Constructivism as a leading paradigm in the didactics of science also changed ideas about the role of the teacher. The teacher is more and more operating as facilitator of meaningful learning activities and less as lecturer. Pupils also get more responsibility for their own learning process. As a result of these and other changes in upper level education nowadays more elbow room exists for project work and skills development within the science curriculum.

Design versus applied science

The starting-point for the development of technology modules was the decision to focus on 'design' instead of 'applied science'. Aiming at mobilising technological talent, the characteristics of technological problem solving and engineering practice are better reflected in design activities than in applied science exercises.

Technological talents are problem solvers with competencies like creativity, constructive work habits and entrepreneurship and make use of critical thinking, decision making, collaboration, communication and representation skills (Dyrenfurth, 1999). Solving design problems successfully demands various competences and applying science is just one of them.

As the term indicates, applied science is just science and the fact that we apply science in a technical context does not make it technology.

Design versus research

In the renewed science curriculum pupils are working on research projects and on design projects. Through these activities they become familiar with the characteristic ways of thinking and problem solving approaches in science and technology. Science teachers have traditionally sufficient experience with research tasks, but not at all with design tasks. What are the differences and similarities and what does that mean for the development of design modules?

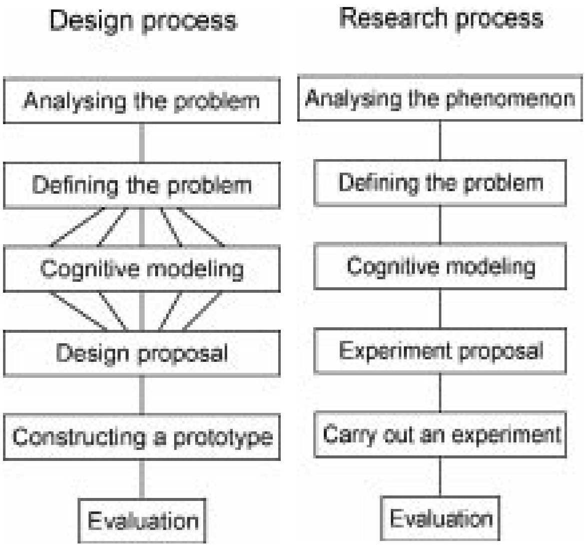

Figure 2.

There is a clear difference in objectives. The object of science is understanding the physical world, the object of technology is changing that world. We can say that the yield of a research activity is knowledge, while the yield of a design process is a product. Where the quality of research is judged by the correspondence with the facts, we can say that the quality of the design is judged by the correspondence with the needs of the focus-group or client.

For pupils these differences in objectives between science and technology also reflect possible differences in motivation. Researchers are motivated by (abstract) thinking, curiosity and the wish to gain a fundamental understanding of the physical world. Designers are motivated by doing, the pleasure of creating things and the wish to elaborate practical solutions for real (human) problems.

At first glance the problem solving processes in both domains look similar but there are important differences, especially in the first three stages of the problem solving process (often cyclic and not linear as might be suggested by the diagrams):

1 a design problem starts with an orientation on people: a mismatch between the real world and the needs of a focus group or client. A research problem starts with an orientation on a phenomenon: a mismatch between the theory and the observed facts
2 design problems are ill-defined, while research problems are not. Goal criteria are not only ill-defined but sometimes even contradictory (Middleton, 2000). As a consequence design problems include much more uncertainties then research problems
3 after the problem definition the search for possible solutions starts (cognitive modelling).

In research we formulate hypotheses and use existing (school) theory to construct a theoretical model which enables us to explain the observed facts. The model is used to predict possible outcomes for experimental verification or falsification.

In *design* the search for solutions is more complex. Where research is dealing with an existing and observable world, in design we are creating a non-existing and not directly observable world. In fact there are *many realisable worlds* and we don't now which world will give the best correspondence with the needs. We have to make predictions about the 'behaviour' of the products to be designed and we never know if we missed a better solution. In the search for solutions *divergent thinking skills* are needed.

In the next stages we find similar problem solving activities in both domains. In these stages we are concerned with planning, construction and testing ideas. For these types of activities more vertical thinking skills are needed.

Attainment targets

Based on this analysis we decided to focus on the first stages of the design process: problem analysis, problem definition and cognitive modelling. The following attainment targets were specified for the initial stages: In the *problem analysis* stage, pupils must be able to identify themselves with the content of the design task and find answers to questions like 'what is the problem?', ' who has the problem?', 'why is it a problem?' and 'what do we want to obtain with a possible solution?'. The starting point for design projects is always a recognisable focus-group or client.

The emphasis on these aspects not only reflects good engineering practice and leads to better designs, but also strengthens the image of technology as a human activity. In this approach doing technology is highlighted as the search for and the realisation of concrete solutions for recognisable human needs. These activities do not so much require smart and possibly narrow-minded whizz kids but rather creative pupils with empathy, communication skills, wide and multi-disciplinary interests and a practical mind.

In the stage of *problem definition* pupils must be able to gather the design requirements from a given context and reformulate general described requirements into testable requirements.

From experiences at pilot schools we learned that evaluation activities are often very limited. In most cases only a correct operation of the constructed prototype is tested. Other requirements are neglected because of vague descriptions.

In the stage of *cognitive modelling* pupils must be able to suggest at least two alternative solutions for the design problem.

Design problems don't have unique solutions and you never know if you have overlooked a promising one. Therefore, generating alternative solutions is vital. That requires divergent or lateral thinking. We agree with Moshe Barak (Barak, 1999) that promoting creative thinking, as a synthesis between lateral thinking and vertical thinking, is one of the central issues in technology education. The question is how to promote this kind of higher order thinking skills?

To support pupils in generating alternative ideas we made use of 'morphological tables', called 'tables for ideas'. Beginning with the determination of *functions*, first the *overall function* and then the most important *sub-functions* to be fulfilled by the product or system are defined. Then a search is made for *solution principles* for all sub-functions, or initially for the most important sub-functions. The result is a matrix of solutions in which each 'path' is an alternative solution. These solutions can be tested against the given requirements. Learning to use 'tables for ideas' is one of the preparatory activities for full design tasks.

Some experiences

In 1996 and 1997 we experimented with 'free' design projects in upper level physics as part of their practical work. Pupils were 'free' to choose and elaborate a design task without preliminary information about designing and the design process. From these experiences we learned (Frederik, 1997) that pupils as novice designers primarily focus on making. There is hardly any reflection on the background of the problem and possible reasons for the design task. Consequently pupils do not tend to collect information about the problem, to formulate requirements for the products they design, to search for alternative solutions and to do solid testing based on pre-defined requirements. These experiences correspond with similar experiences in the design departments of technical colleges/universities. Novice designers tend to pay little attention to problem analysis and the process of generating ideas for solutions.

In 1997 we started with the development of design modules for use in biology, physics and chemistry. For common use in all modules we developed a design manual and a portfolio document based on the above discussed attainment targets. The design manual is a reference book with general instructions (methodology) for each stage of the design process. The portfolio document enables pupils to report the results (e.g. table for ideas, arguments, decisions) of different stages in the design process, and supports supervision by the teacher. For each design task a knowledge database (reference document) was provided for background information.

These modules were tested in different pilot schools in the school years 1998/1999 and 1999/2000. Compared with the results in 1996/1997 these experiences certainly showed improvements in some process skills. Pupils paid much more attention to problem analysis, problem definition and evaluation.

Creative thinking skills are still poorly demonstrated. Yes…, as a result of their design work most pupils produce nicely filled in tables for ideas. However, closer examination shows that in many cases these tables are filled in as proforma, only because it is demanded by the teacher. Alternatives are not really judged and there is a strong tendency to elaborate the first idea which came in mind. Pupils show much creativity in finding justifications afterwards. It seems to be very difficult to change this pattern.

A possible solution?

A problem with process instructions in the form of design manuals and 'tables for ideas' is that they are functioning too much as straightjackets. These instruments do not offer natural incentives for generating new ideas. In real-life design practice such incentives are offered in direct communication

with the client or *problem owner*. For a professional designer it is of vital importance to satisfy the needs of the focus-group or client and generating alternative ideas is often a result of such communication processes.

Also in school practice enabling direct communication with an ‘owner of the problem’ can serve as a natural incentive for divergent thinking. It can stimulate pupils to reject early ideas, to elaborate new ideas and even to use tools like morphological tables in the search for alternatives. Direct communication with a problem owner also strengthens the identification with the problem (important for motivation!) and the quality of problem definition and product evaluation.

In the next year we start experiments with problem owners as information source in different stages of the design process. In these experiments different scenarios will be explored: real problem owners, fictitious problem owners at school and problem owners on the Internet. Although we foresee a lot of practical problems we see it as a challenge to explore the feasibility of this idea.

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Function	*Elaborations* 1	*2*	*3*	*4*
1A Marking the route wire	Painted stripes	Reflecting stripes	Magnetic stripes	Electric
1B Representing route information	Sketch 1	Sketch 2	Sketch 3	Sketch 4
2 Measuring route information	Light sensor	Lamp + light sensor	Reed switch	Magnetic field sensor
3 Processing route	Comparator	Comparator + inverter	Comparator +counter	Software information
4 Observing route information	Buzzer at the stick	Buzzer at the clothes	Vibrator at the wrist	

Figure 5: Table for ideas.

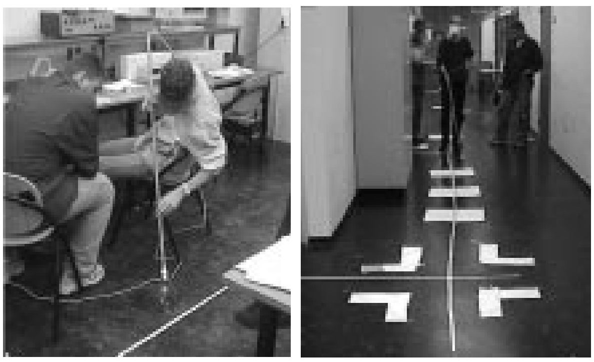

Figure 6: Testing the light sensor and testing the system.

An example

Design a system that allows blind people to find a route in public buildings (see Figures 4, 5 & 6).

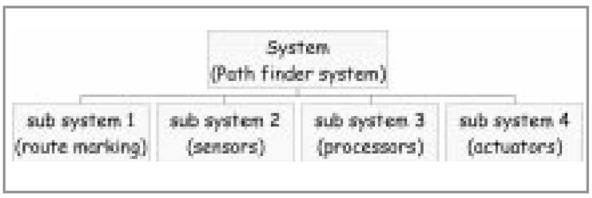

Figure 4: Functions.