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Pre-university physics presented in a thematic and systematic way: experiences with a Dutch Physics Curriculum Development Project

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Pre-university physics presented in a thematic and systematic way: experiences with a Dutch Physics Curriculum Development Project

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In the Netherlands a team of people from universities and schools is developing a new, three-year curriculum for pre-university physics education for the age group 15–18. This curriculum emphasizes the connections between physics and daily life, society and technology and provides a better preparation for pupils' further education.

Compared with traditional courses this course gives more attention to topics in modern physics and to the development of research skills, and pupils are shown how science is practised. An experimental new examination programme has been constructed in connection with the curriculum. The curriculum itself consists of thematic units centred around realistic and relevant contexts, as well as systematic units, the main aim of which is to develop fundamental concepts and problem-solving skills.

In the classroom the new course stimulates the use of a variety of teaching methods and encourages differentiation. Evaluation research and research into conceptual development are also being done in connection with this course.

Introduction

In pre-university physics in the Netherlands much emphasis is laid on preparing pupils for their future science studies. Although this aspect is of course important, there are also other important educational objectives which are recognized nationally, as well as internationally (see, e.g., ASE 1981, NTSA 1982, UNESCO 1982). The project described in this article adds two further objectives which are innovatory to a certain extent. First of all, pupils should be given the opportunity to think for themselves and develop as responsible citizens. Secondly, pupils must become acquainted with current developments and practice in the world of science and with the applications of science in society. The first of these objectives has already been implemented in curriculum projects developed for lower levels of physics education (Hooymayers, 1982). The second is considered to be of particular importance in pre-university physics education.

This article describes the ways in which these educational innovations are being worked out and incorporated in a new physics curriculum. In addition, a description is given of the history of the project, the methods used and the structure of the planned curriculum, 75% of which is already complete (1985) in an experimental version. Finally, we describe the kind of research that is being done in connection with the curriculum development and comment on the implications of such research.

Contemporary pre-university physics education: some issues

In the Netherlands, pre-university physics (vwo) is a five-year course for pupils aged 13 to 18 who are in the 2V–6V forms of secondary education (see figure 1). In the first two years (2V–3V) the overall curriculum is the same for all pupils. During the last three years (4V–6V) the pupils choose and study seven or eight examination subjects which serve as stepping stones to certain university courses.

Traditionally physics education in vwo consists of two stages: junior education in 2V–3V and senior education in 4V–6V. The junior stage consists of two years of physics education for all pupils with little emphasis on the final examination. In the top two forms of the senior stage physics is taken as an examination subject by only about 50% of the pupils. The (final) physics examination is in two parts: 50% is a written examination set by external examiners and 50% is a written and practical examination set by the schools. Both parts are based on the national examination programme.

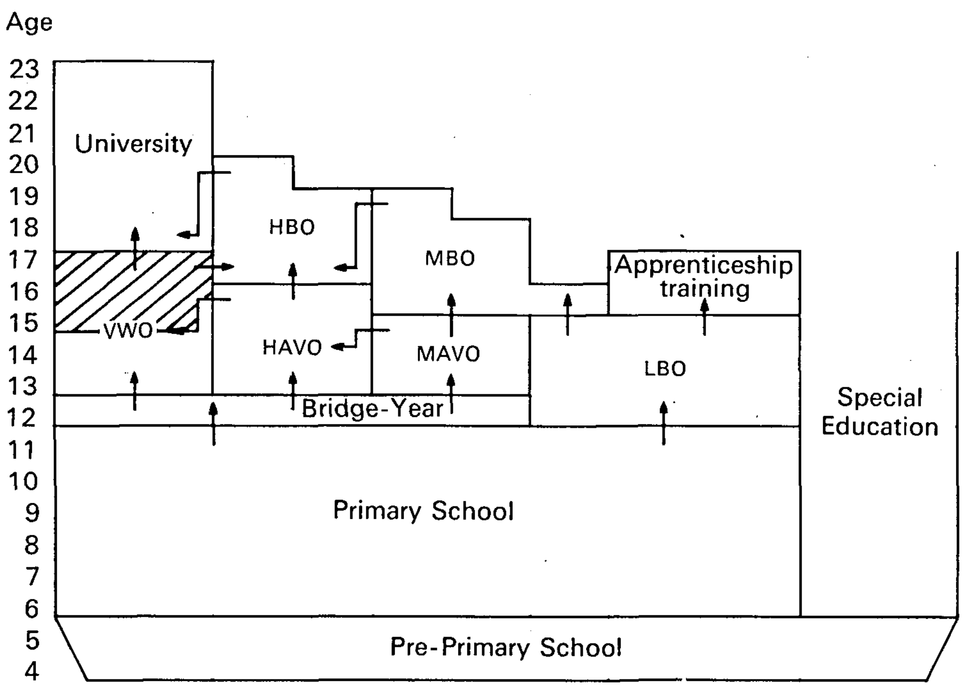

Figure 1. The educational system in the Netherlands. The working area of the VWO project has been shaded.

The examination syllabus contains not only a list of skills to be acquired but also an extensive list of topics, some compulsory and others optional. About 90% of the 320 physics 'hours' (normally lasting 50 minutes) in the senior stage are devoted to the compulsory subjects, the main emphasis being on the structure of physics; little attention is given to modern topics; these are included in some of the optional topics, but remain poorly represented in the curriculum as a whole.

For the junior stages of VWO, HAVO and MAVO (see figure 1), PLON has developed an innovative curriculum which was completed recently (Hooymayers 1982, Wierstra 1984). In the materials used, attention is given to the application of physics in the pupils' own world. More open teaching situations and pupil involvement are encouraged, particularly in the form of practical work. The thematic approach means more variety in the ways of dealing with physics. The project has led to important innovations in the teaching of junior physics in many schools in the past two decades. Therefore, more and more the senior stage VWO physics compares unfavourably with the junior stage. For a few years now practical work has been a compulsory part of the final examination, but in fact many schools do not prepare their pupils adequately for this because the existing curricula are usually not geared to it.

Many difficulties arise especially in 4V. The pupils are then at a level of cognitive development which allows for a limited degree of formal thinking. Nevertheless, they are expected to work on abstract physics at examination level, although a substantial percentage of the pupils will not even take a physics examination. The contrast with the junior stage is striking, and often very discouraging to the pupils.

The VWO-project for the senior stage was started by PLON in 1980, in connection with the developments at the junior stage and at other educational levels. The PLON project is co-operating with the physics education departments of the University of Amsterdam and the State University of Groningen. The innovative characteristics of this project can be summarized as follows:

- equal weight is given to the three general educational objectives mentioned in the introduction;
- there is a gradual transition from the junior stage to the more mathematical-physical senior stage;
- topics from modern physics are introduced;
- more attention is given to independent work and to the development of problem solving abilities;
- opportunities are created for differentiation with regard to future studies, and with regard to the variety of learning styles and the interests of pupils;
- the development of basic concepts is carefully planned throughout the curriculum;
- the link between physics and mathematics is given more prominence (particularly in relation to innovations in the mathematics curricula in VWO).

Form and progress of the project

About 25 teachers from all over the Netherlands took part in the opening conference of the project. At this conference participants studied several physics curricula, which either existed already or were under preparation and which were intended for the same age group. Special attention was paid to the PLON HAVO project (Eijkelhof and Verhagen 1984) (the HAVO level gives access to higher vocational training, see figure 1) and to the Nuffield Advanced Level project. One result of the conference was that nearly all the participating teachers decided to work on the development of a thematically-structured VWO curriculum. The teachers formed four regional 'writing groups' each with 6–8 members and were guided by the university departments and by PLON. They also agreed to try out the new materials in the schools where they worked.

The decision to involve teachers not only in the classroom-trials (as in the PLON HAVO project) but also in the course development certainly did pose problems. The development of teaching material that is fresh and new and of consistently high quality is very time-consuming. Although teachers in the Netherlands do not have to travel great distances, discussions and meetings with colleagues are an extra burden, particularly to those in full-time employment. In the past few years it has become quite clear that a great deal of time and energy needs to be invested before a productive stage is reached. However, the main advantages of the direct involvement of teachers have proved to be:

- the range of expertise that becomes available;
- the best possible use can be made of teachers' practical experience as far as choices of objectives are concerned;
- the starting position facilitates try-outs and the circulation of new materials.

Most of these teachers are still participating in the writing groups. Some other teachers have joined in recently, mainly from schools that are also participating in the PLON HAVO project. At the moment we have five active writing groups. Of course, in such an extended project involving 25 teachers, curriculum co-ordinators and researchers play a vital role and organization and coordination are important. Plenary meetings and conferences are held at set times. These are of vital importance for testing newly-written units, for keeping planned developments within the framework of the curriculum as a whole and for making important decisions. A special central group has been formed as well to organize and co-ordinate activities.

In the first few years three important issues affecting mainly the 4V form were discussed at length: the development of a common fundamental view, the general characteristics of a curriculum unit and the development of materials in a writing group.

In the school year 1983–1984 four trial schools started using the complete 4V curriculum. Other schools went on trying out one or more single units. At the same time, the decision was made to extend the working area of the project to 5V–6V and to draw up an experimental examination programme.

This Experimental PLON Examination Programme (EPEP) can be used to compare the innovative curriculum with the standard national syllabus and, at the same time, serves as a guideline for coordinating the units being developed by the writing groups. In the EPEP, an effort is made to link the curriculum design with the fundamental ideas about innovation. The EPEP occupies a key position in the VWO project for two other reasons: the provision of a specially adapted final examination makes the innovative experiment more complete; at the same time pupils in the trial schools are offered an adequate examination.

Fundamental views on physics education

On the basis of the general objectives of pre-university education mentioned above and on the basis of innovations introduced by PLON in the HAVO and MAVO courses and in the junior VWO stage, five fields of innovation have been chosen for the senior VWO stage. These fields bring new accents to pre-university physics education, which will have to be incorporated in the experimental VWO curriculum.

1. Pupils' environment

In the daily life of pupils there are many aspects which can be used as contexts to make physics knowledge significant and practical. One can think of consumer behaviour, the human body, risk assessment in traffic or in situations involving ionizing radiation, hobbies, etc.

2. Social developments

Science influences society in many aspects. This is one reason why physics education has to deal with topics such as industrial technology and innovations, environmental problems, energy supply, defence and safety, etc. (Eijkelhof 1985).

By exploiting these two fields of innovation one can integrate into physics education the desired elements of independence and responsibility.

3. Historical development of physics

Physics is not a static arrangement of knowledge; it is always developing under the influence of new discoveries, new technology and changes in social circumstances. This means that topics like the interlinking of physics and technology and the explosive growth of physics in our time should be included in pre-university education. Furthermore, attention should be given to the historical development of important physics concepts like particle-wave duality, energy and mass, the electron.

4. The world of science

When pupils are made to realise that physics is not an abstract science but involves people and is essentially a human activity their critical and creative abilities are stimulated. Pupils should therefore be introduced to topics such as science management and the responsibilities of the scientist.

The purpose of the objectives 3 and 4 is to acquaint the pupils with scientific practice.

5. Physics in further education and professions

The VWO project tries to reformulate the objectives of physics education in that it puts more emphasis on physics as a professional activity and on physics as a basis for the study of other sciences, and focuses on applications of physics, e.g. microcomputers. It will be shown below that *versatility* in basic concepts is an important issue in this connection.

In the EPEP, after the general educational objectives have been mentioned, the innovative characteristics are used to account for the choices that are made in taking over skills and topics from the traditional list. The EPEP can be divided into two parts according to the degree of *versatility* that is required from the pupils.

One part deals with basic concepts that have to be known or handled with a high degree of versatility. This means that pupils must be able to use these basic concepts in a great variety of theoretical or experimental contexts, and choose a form that is appropriate to the idealizations of approximations that are needed to solve the problems set. This part includes concepts from the following fields: mechanics, energy, oscillations and waves, electric currents, electric and magnetic fields, corpuscular models of solids, liquids and gases, atoms and the atomic nucleus.

The other part deals with topics that have to be known or handled within a single context or within a limited range of contexts. For example, concepts connected with topics like semiconductors, sound or meteorology can be restricted to one or two contexts.

Thematic and systematic units

In the junior stages, as in the MAVO and HAVO senior stages, the units are thematic. This means that the coherence of a unit is established by a central question taken from a context in which physics plays an important part. Reasons for developing thematic units are:

- new concepts are more easily integrated into the pupils' intricate network of relations and associations;
- the retrieval process is facilitated: the relation between the physics concepts and familiar problems posed in a thematic unit provides the nodal points for selection of the physics needed for the solution of new problems;
- pupils prefer to study physics in a recognizable context that shows the usefulness of the physics involved.

These are the reasons why thematic units have been constructed for the senior VWO stage as well.

However, another aim of pre-university physics is to give pupils insight into the systematic structure of physics itself. This is why, in addition to the thematic, context-centred units, another kind of unit ('block') was developed. The main objectives of these blocks are:

- to give pupils insight into the systematic structure of physics, particularly in relation to motions, energy and work, and fields (e.g., electric);

Table 1. The units of the experimental VWO curriculum. The 6V programme is not yet complete.

4V (three 'hours' a week)	5V (four 'hours' a week)	6V (four 'hours' a week)
The human body	Sports	*Satellites*
Music	Electric motors	Electromagnetic waves (*block*)
Traffic	Work (*block*)	How does science develop
Motions (*block*)	Physics around 1900	Open research
The weather	Automation	Preparation for examination
Energy	Particles in fields (*block*)	
	Ionizing radiation	
	Optional investigations	

- to broaden and deepen selected basic concepts and widen their applicability by means of mathematical methods;
- to develop problem-solving abilities in (real) situations from everyday life or from science and to stimulate the use of heuristic strategies in problem-solving.

The innovative VWO curriculum therefore now consists of both thematic and systematic units. These units are listed in table 1.

Some of the thematic units of the VWO curriculum are borrowed from the PLON HAVO project or they use parts of PLON HAVO units, especially at the 4V level since that grade does not differ very much from the 4 HAVO grade (except in tempo).

Standard structure of thematic units and of blocks

A standard structure has been developed for the thematic units. Experiences with the junior grades (van der Valk 1984) and with the HAVO project have had an important influence here. A different structure has been chosen for the block units: in a thematic unit a 'general thematic question' is used as an ordering principle, in a block unit the systematic structure of the physics itself is the ordering principle. The standard structures of thematic units and of blocks are sketched and compared in figure 2.

Research

Research in connection with the new course falls into two categories:

(*a*) research into the general usefulness of the materials, and

(*b*) research into the effects that various elements in the curriculum have on the learning process.

The two types of research can be practised in relation to the curriculum as a whole and in relation to the separate units.

Structure of a thematic unit

Orientation
- introduction to the thematic questions
- brushing up existing knowledge
- activities in this unit

New subject-matter
- introduction of new concepts
- broadening of skills
- assimilation by means of activities

Differential period
- application of subject-matter to different domains within the theme
- assimilation of the new concepts; no additional concepts
- classroom reporting

Deepening and/or generalization
- extending concepts to a higher abstraction
- making concepts more versatile within the chosen context

Conclusion
- evaluation of the thematic questions
- relations with environment/society/technology/scientific practice
- test

Note: Several variations are possible within this model.

Structure of a block unit

Orientation
- introduction to the block questions
- brushing up existing knowledge
- activities in this block

Broadening and deepening of subject-matter
- using familiar concepts in new contexts
- linking up concepts from different themes
- defining the concepts more sharply
- giving a mathematical form to the concepts
- exploring the limited applicability of concepts

Problem-solving
using the deepened concepts in new 'real life' situations

Retrospection

Test

Note: In one block the cycle of broadening/deepening and problem solving is gone through two or three times.

Figure 2: Structure of experimental VWO curriculum units.

These two categories can be broken down still further:

ad *a*:

- research into internal inconsistencies in the curriculum contributing also to a clarification of objectives;
- research into the organization of new working methods (e.g., the microcomputer) in the classroom and into the development of didactic methods for introducing new topics for modern physics or applied physics.

ad *b*:

- research into the use of skills by the students and the development of skill-testing devices;
- research into concept development and into problem solving in a context.

The types of research mentioned above are important in connection with the revision of the materials, the content of courses for teachers, and as a contribution to a decrease in the mental separation between learning, thinking and acting of the pupils.

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