2nd International IPN-YSEG Symposium
Context-Based Science Curricula

Physics in personal, social and scientific contexts

A retrospective view on the Dutch Physics Curriculum Development Project PLON

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> We don't need no education
> We don't need no thought control
> No dark sarcasm in the classroom
> Teachers leave the kids alone
> Hey teacher, leave us kids alone
>
> Pink Floyd (1979)

Introduction

PLON – the Dutch acronym for *Physics Curriculum Development Project*. PLON – a project that developed full, context-based – or, in our opinion, STS-flavoured – courses (including student's textbooks, teacher's guides, technician's manuals and even to some extent examination papers) for secondary physics education in the various Dutch ability streams: lower ability (MAVO), average ability (HAVO) and pre-university (VWO). PLON – a project that came into existence in 1972 and was – be it only officially – terminated in 1986... representing roughly fifteen years (and more) of curriculum development and associated research.

The PLON curricula were context-based in the sense that the students' 'lifeworld' was taken as a starting point, with an emphasis on technological artefacts and natural phenomena in junior secondary education (grades 8-9, age 13-14), supplemented with an emphasis on socio-scientific issues and the nature of science in senior secondary education (grades 10-12, age 15-17). The aims of physics education put forward by the PLON project have evolved over a number of years into a balance between preparing students for, on the one hand, further education and/or future employment and, on the other hand, coping with their (future) life roles as a consumer and citizen in a technologically developing, democratic society. It was tried to find a balance between these two aims by developing teaching/learning units in which basic physics concepts and skills – covering most of the traditional content areas in physics education such as for example kinematics, mechanics, energy, electricity and magnetism, optics, sound and matter – are dealt with in a personal, social or scientific context. Therefore, the PLON curricula aimed at 'physics for all' and not just the one percent future specialists in the classroom.

1 Theory

Theory – Was there an educational, psychological or whatever theory behind the curriculum? The answer to this question depends on what one considers to be theory. But no, probably not. At least not that we were aware of at that time. There were, however, a number of assumptions about the desired characteristics of physics teaching and teaching materials. Assumptions to be described below...

Appearance – Why did the curriculum make its appearance in its particular time and place? In

December 1970 the annual conference for Dutch physics teachers was devoted to Harvard *Project Physics*. The audience was excited about this approach to physics education, especially about its cultural and historic context, the readers and the practicals. It was felt that we needed such materials for our students to make physics as attractive as it could be in our view as teachers. Following this conference a proposal was sent to the government for funds to finance a project in which the good ideas from the new physics curriculum waves such as the Project Physics, the Physical Science Study Committee and the Nuffield materials could be made available to Dutch physics teachers through materials. And indeed, funding became available for a curriculum development project with ‘developing proposals for updating and modernising the existing physics curricula’ as its main task, starting with junior secondary education in which physics is a compulsory subject. In the first years a lot of inspiration was found in American, British, Australian and German curriculum development projects and work was limited to junior secondary education (grades 8-9). In the second half of the project’s lifetime the materials got their own distinct style and conceptualisation, and most attention went to other ability streams in senior secondary education (grades 10-12). At first the materials were strongly related to the local environment of the students and to the technology surrounding them. Later, in both junior and senior curricula more attention was paid to the interaction between physics, technology and society (STS). An overview of the curricula and their teaching units is provided in the appendix. The box on ‘science and STS education’ gives some general background information about their appearance at that particular time and place.

Science and STS education

Science education at the secondary level has traditionally emphasised an adequate mastering of scientific concepts and the development of scientific skills, in order to lay down a solid foundation on which students can rely when entering those forms of tertiary education in which science knowledge and skills are considered essential. However, this would apply to only a minority of students in secondary education. Therefore, this curriculum emphasis of *solid foundation* (Roberts, 1982) does not exclusively aim at preparing students for further science education at the tertiary level. Science education is considered – or at least expected or hoped – to contribute to the ‘personal development’ of all students in terms of a growing awareness of the cultural importance of science and an increasing ability to ‘think scientifically’.

Until a few decades ago most science courses for reaching these general aims could be characterised as having a rather academic, theoretical nature. In this bare, formal and mathematical science, little or no attention was paid to technological applications and to social implications of science and technology. For those students not planning to continue their science studies at the tertiary level, the value of this type of science education for their ‘personal development’ might have been hard to recognise. In their perception science could easily turn into a difficult and unworldly subject, dealing with – for example – the mathematics of non-dimensional point masses on inclined frictionless planes. A subject with little or no perceived practical use after having left secondary school – *We don’t need no education...*

During the 1970s this type of science education started to be questioned, not only by curriculum developers and teachers, but also by different pressure groups in society (Fensham, 1988a; Solomon, 1994; van den Akker, 1998). Some textbook authors and science teachers hoped or even expected that relating science to everyday life phenomena (be they technological or natural) would make science teaching more interesting for a larger proportion of their students. The ‘problem’ with science education as perceived by them was one of contents, and not one of top-down transmission of these contents to the students through talk-and-chalk – an issue to be somewhat further addressed in section 5.

At about the same time different pressure groups in society started asking for attention to be paid to technology within the existing science curricula. Some groups argued for this change in order to make the students (more) aware of the importance of science and technology for maintaining a sound economy. The idea probably was that this would counter the increasingly negative image of industry due to its detrimental impact on the environment. Other groups used this impact on our environment to argue for attention to be paid to alternative technologies and an ecological lifestyle necessary for survival in the long run. The tension between economic and environmental considerations led to a growing intensity of public debate, at first focusing on our energy future but very soon extending to a more general discussion of the impact of scientific and technological developments on society in fields like (nuclear) armament, information technology, genetic engineering, etc. At the beginning of the 1970s some optional STS education started to develop at university level: STS courses were developed and taught, research started to deal with questions put forward by trade unions, environmental pressure groups and the like.

The increasing public debate on the impact of science and technology on society, and the emergence of STS education at university level led to a growing internal and external pressure on secondary science education to also ‘do something’ in the area of ‘scientific and technological literacy’. Science education might provide the students with some basic knowledge, helping them to understand the issues concerned and to participate in the public debate in an informed and balanced way. Science education might also present a framework for structuring the muddle of unbalanced, biased and fragmentary topic-of-the-day information on these complex science/ technology-related social issues. So, a shift of curriculum emphasis towards *science, technology and decisions* (Roberts, 1982). Such a shift of curriculum emphasis could be seen as an alternative operationalisation of the somewhat vague ‘personal development’ component of the earlier mentioned solid foundation curriculum emphasis.

And gradually the PLON project started to work in that direction: developing STS-flavoured curricula and teaching materials for secondary physics education.

Assumptions – What assumptions did we make about why our approach would be worthwhile? The emergence of STS education in Dutch secondary education through the PLON project reflects a broadening of contents and skills to be ‘covered’ in science education. Traditional science content knowledge had to be supplemented with context knowledge, such as knowledge about science/technology-related social issues. And traditional science skills had to be supplemented with context skills, such as issue-related decision making. This broadening of contents and skills was more than just ‘adding on’. It was the intention that traditional science content would facilitate a better understanding of these issues.

The main rationale for this kind of education can be briefly characterised as “science for all, by promoting activity-based teaching and learning in relevant lifeworld contexts” (Lijnse *et al*., 1990). From such teaching it was expected that students would experience the content taught as more relevant, and that they would be better able to understand and connect the concepts learned to their out-of-school world (Lijnse, 1995). These assumptions cannot be considered to be derived from general, research-based (or big-T) theories about teaching and learning – disregarding the question whether such general theories offer any useful guidelines for developing concrete teaching materials and adequate classroom practices. At most, the above mentioned assumptions could be considered to stem from practitioners’ experiences and intuitions about what constitutes attractive teaching and effective learning at the classroom level. Experiences and intuitions which could – over time, in the process of curriculum development and evaluation – grow into something that reflects an action-based (or small-t) theory.

2 Goals

A context-based curriculum – Why context-based? What does context-based mean in our case? The rationale for developing a context-based curriculum has already been summarised in the previous section under the heading of assumptions. The curriculum being context-based in our case meant that we took the students’ ‘lifeworld’ as a starting point, with an emphasis on technological artefacts and natural phenomena in junior secondary education, supplemented with an emphasis on socio-scientific issues and the nature of science in senior secondary education. Therefore, the word ‘context’ in the PLON curricula refers to a coherent collection of practical situations that ask for a better understanding and/or decisions to be made at a personal and/or social level, such as for example traffic safety, fuel consumption (and its costs and environmental impact), applications of ionising radiation (and their benefits and risks) and applied versus fundamental scientific research.

Conceptual frame – What is the conceptual frame of the curriculum? This question has to be answered at two levels: the level of a teaching/learning unit and the level of the curriculum as a whole.

- **The unit level** – The general format of a unit is pictured in Figure 1. The unit starts off with an orientation, introducing a basic question taken from the society students live in, and regarded as relevant to the students – at least in the eyes of the project team – with respect to their (future) life roles as a consumer and citizen in society. The choice of these basic questions and the accessory dilemmas will be dealt with in the next section under the heading of content selection. The second part of a unit addresses basic information and skills: the physics relevant for answering the basic question. This part is followed by a number of options in which groups of students independently do some further work on aspects encountered in the unit's previous part and report their findings to other groups in class. Then the basic question turns up again in the last part of the unit, in which the physics concepts and skills are broadened and/or deepened by applying them to situations in which the basic question is prominent: does the physics taught help in finding answers, help in being able to cope with a technological device, a consumer decision, a socio-scientific issue? This turning back to the basic question – to society – is essential because it reflects the relevance of our physics teaching. An example of a teaching unit with such a general format is given in the box below.

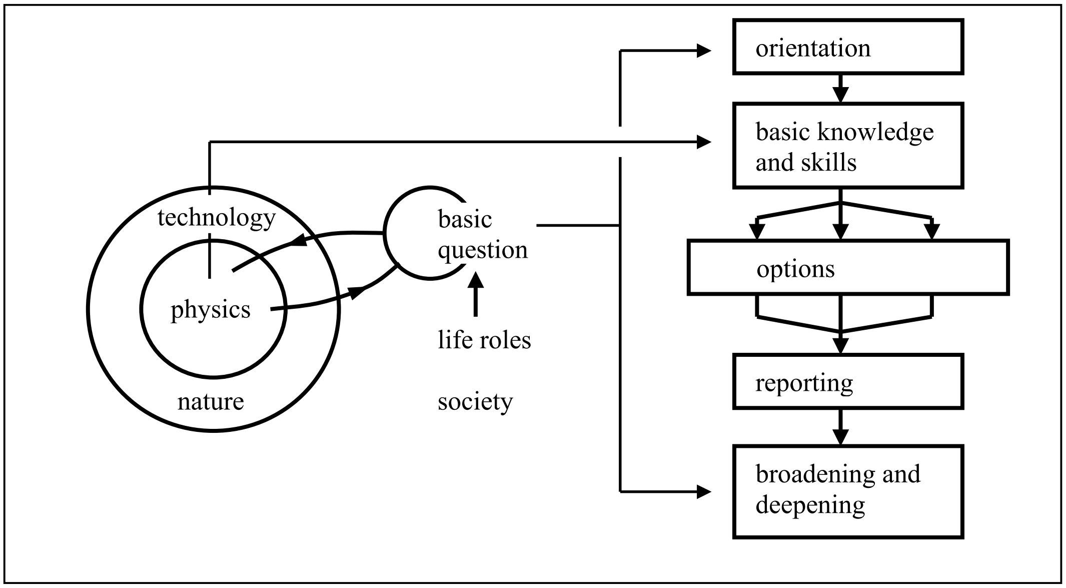

Figure 1 – General format of a teaching unit.

An example: the unit *Ionising Radiation*

The basic question in the unit *Ionising radiation*: How acceptable are applications of ionising radiation to you? The unit starts off with an orientation, introducing a number of everyday life situations in which the use of ionising radiation might be an issue, and giving an idea of the nature of the risk concept (a combination, but not a straightforward one of probability and effects).

The next part contains basic information and skills about the nature, effects and sources of X-rays and radioactivity. Concepts important in risk assessment are introduced, such as half life, activity, dose, somatic and genetic effects.

After dealing with the basic information, groups of students start to work independently on either one of the three options: nuclear energy, nuclear arms and the use of radiation for medical purposes. Background information on risk and safety aspects of each of these areas of application is given or collected by the students. In several subsequent lessons, students report their findings to other groups in the class.

In the final part of the unit (broadening and deepening) procedures are dealt with to analyse and evaluate personal and societal risks, like being prescribed a brain scan or like the dumping of radioactive waste into the ocean. A framework for evaluating risks is presented through a series of questions on advantages, on short and long-term risks with and without the specific application and on possibilities for risk reduction.

- **The curriculum level** – There might be two ways of characterising the PLON curricula with respect to their conceptual framework: with the help of the concept of curriculum emphases and with the help of a content/structure-diagram.

In terms of the seven curriculum emphases – each representing a coherent set of messages to the student about science and providing answers to the student's question of 'why am I learning this?' – as introduced by Roberts (1982), the existing curricula in the Netherlands could be characterised by a 'correct explanations' and a 'solid foundation' emphasis. The shift of emphasis strived for in the PLON curriculum is to balance these with the five additional curriculum emphases of 'everyday coping', 'science, technology and decisions', 'scientific skill development', 'structure of science' and 'self as explainer'. As the basic questions set the scene for the units, these curriculum emphases should be reflected into these questions. The box below gives an example of one of the PLON curricula characterised in terms of curriculum emphases.

An example: the PLON HAVO curriculum

The PLON curriculum for HAVO (grades 10-11, average ability stream) consists of the ten units listed in the matrix of Figure 2. In that matrix – based on an earlier description of this curriculum (Kortland, 1987) – is visible which of the five additional curriculum emphases are to some degree present in each of these units next to the two more traditional ones of 'correct explanations' and 'solid foundation'.

Teaching units	Curriculum emphases						
	EC	SS	STD	SSD	CE	SE	SF
Comparing				x			x
Weather changes	x				x		x
Music	x				x		x
Traffic	x			x	x		x
Electrical machines	x				x		x
Energy and quality			x		x		x
Matter		x	x	x	x	x	x
Light sources	x			x	x		x
Ionising radiation			x		x		x
Electronics			x		x	x	x

Figure 2 – Characterisation of the PLON HAVO curriculum in terms of the seven curriculum emphases.

The core of the seven curriculum emphases could be summarised as follows:

- Everyday Coping (EC) – functioning, maintenance of technological artefacts, natural phenomena
- Structure of Science (SS) – intellectual enterprise: development of scientific knowledge
- Science, technology & decisions (STD) – STS: science/technology-related social issues

- Scientific Skill Development (SSD) – means of scientific inquiry
- Correct Explanations (CE) – ends of scientific inquiry
- Self as Explainer (SE) – process of explanation, cultural/historical context
- Solid Foundation (SF) – prerequisite for further study

The ‘structure-of-science’ and ‘self-as-explainer’ curriculum emphases are not very prominent in the PLON HAVO curriculum because of the questionable relevance for students at this level, and their assumed lack of interest in these areas. In the PLON VWO curriculum which prepares students for university entrance these emphases get more attention.

From the shift of emphases embodied in the PLON HAVO curriculum a more relevant curriculum emerges, presenting a more adequate image of physics with more appeal to different groups of students at different moments. The indication of curriculum emphases in the PLON HAVO curriculum might give rise to the impression that the attention paid to the development of physics concepts is marginal. This, however, is not the case. The social and technological contexts for the units have not been chosen at random, but are covering most of the important physics topics. By learning physics concepts in a meaningful context students have the opportunity to become more familiar with the meaning these concepts have. On the other hand, one of the limitations of this way of learning is the difficulty of a transfer of concepts from one context to another. In the PLON HAVO curriculum this limitation is partly accepted. However, in the PLON VWO curriculum in several units attention is being paid to a generalisation of physics concepts learned earlier in specific units.

Another way of characterising the PLON curricula would be to compare it to other STS-like projects at that time (Kortland, 1992). Figure 3 depicts this in terms of the position of several contemporary STS science courses on two spectra: one of contents (Fensham, 1988b) and one of structure (Aikenhead, 1990).

Contemporary projects:

- SATIS: Science and Technology in Society
- PP: Harvard Project Physics
- PLON: Physics Curriculum Development Project
- SISCON: Science in a Social Context
- SaS: Science and Society

Recent projects:

- Salters Chemistry and Physics (Salters)
- Chemie im Kontext (ChiK)
- Chemistry in the Community (ChemCom)

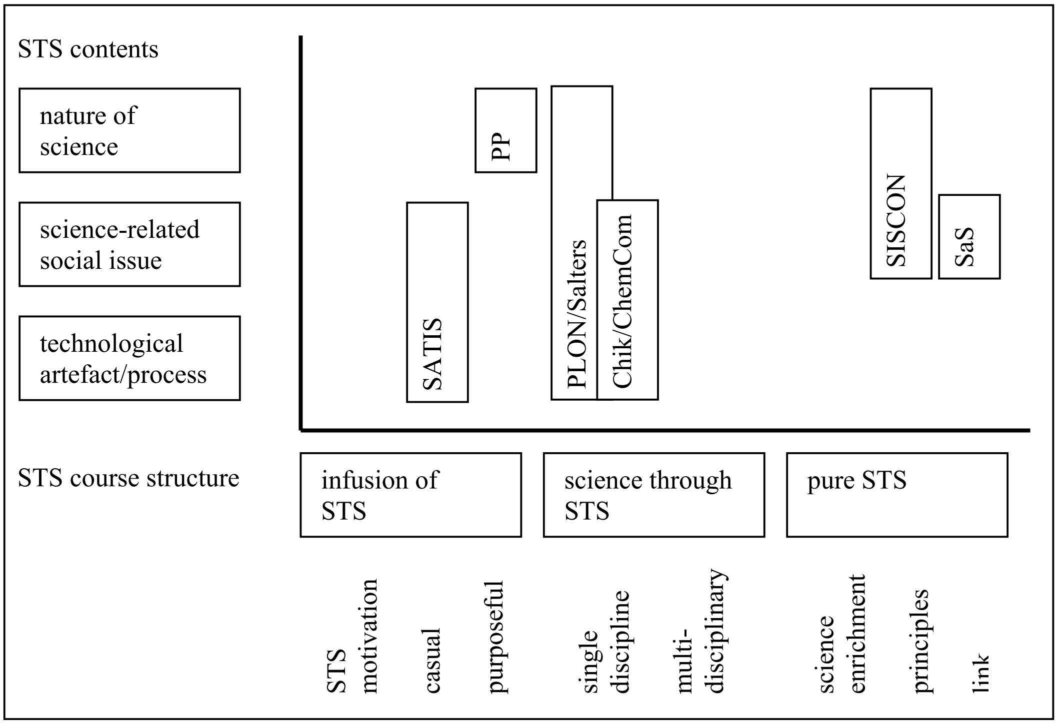

Figure 3 – A classification of context-based and/or STS science courses.

In addition, Figure 3 also shows the position of some of the projects under consideration at this

2nd International IPN-YSEG Symposium on *Context-Based Science Curricula*: *Salters* Chemistry and Physics, *Chemie im Kontext* and *Chemistry in the Community*. It has to be noted, however, that an additional closer look at the actual teaching materials would be necessary in order to validate these classifications, especially in the area of addressing the 'nature of science' (which in the Salters materials – as well as in the PLON materials – probably doesn't get much emphasis).

Aims – What is the 'philosophy' of the curriculum, what are its aims? The aims of physics education put forward by the PLON project have evolved over a number of years into a balance between preparing students for *further education and/or future employment* and for *coping with their (future) life roles as a consumer and citizen in a technologically developing, democratic society*. The first aim emphasises an adequate mastering of physics concepts and skills and providing an orientation on their use in different professions and types of further education. The second aim emphasises the use of physics as one of the tools for (more) thoughtful decision making at a personal and societal level. In the project it was tried to find a balance between these two aims by developing teaching/learning units in which basic physics concepts and skills are dealt with in a personal, social or scientific context (Kortland, 1987; Eijkelhof & Kortland, 1988).

As far as students' decision making in the PLON units is concerned, great care was taken to avoid any kind of indoctrination – as the possibility of indoctrination was one of the objections raised to giving the physics curricula a distinct STS flavour (Eijkelhof *et al*., 1984). The project's value position regarding the students' decision making in an educational setting was therefore one of individual responsibility of the student: whether or not the student makes a decision, when he or she will do that and which way the decision turns out is for him or her to decide and is not to be 'dictated' by the teaching/learning unit or the teacher – *We don't need no thought control...*

At a more down-to-earth level the aims were making physics more relevant and attractive to students (by context-based and activity-based teaching/learning, respectively) while at the same time adequately preparing them for taking the nation-wide final exams at the different ability levels (MAVO, HAVO and VWO) successfully. As compared to the traditional curricula it was aimed at students having at least the same level of competence as far as physics contents are concerned, while in addition they would be better able to apply this knowledge to practical problem situations, have better investigation and communication skills, would be able to recognise (new developments in) the interplay between science, technology and society and to contribute to debates in this area.

3 Design and development

Organisation – Who made the design, who worked out the material, how was the development organised? Development of curriculum ideas and their translation into teaching materials was done by a university-based project team, in majority consisting of former secondary school physics teachers. The materials were used in a limited number of trial schools. Development had a cyclic character, in which the start of each cycle was fed by lesson observations by the project team, ideas and comments from trial school teachers and evaluation results. Through the frequent meetings of a preparatory and evaluative character between the project team and the group of trial school teachers during each cycle the teachers had some influence on the materials. At a later stage, in the development of the PLON VWO curriculum, trial school teachers were also engaged in writing the teaching materials.

The project team developed full, closed curricula (including student's textbooks, teacher's guides, technician's manuals and even to some extent examination papers) for secondary physics education in the various Dutch ability streams: lower ability (MAVO), average ability (HAVO) and pre-university (VWO). Support for teachers was provided through the teacher's guides and technician's manuals and through the preparatory and evaluative meetings with the project team as mentioned above. Especially these meetings were important for the teachers, as they provided them with a platform for exchanging ideas for and experiences from classroom practice, for mutual support and learning from each other. It has to be noted, however, that these meeting were also highly informative for the project team with respect to the feasibility of the materials that were developed.

Resources – Which material and personal resources were available for the development of the curriculum? The project was fully financed by the Dutch Ministry of Education, with additional support in terms of working facilities for the project team from Utrecht University. In the first years the PLON team consisted of three curriculum writers (physics teachers), one evaluator (psychologist), a technician and a secretary on a full-time basis. In later years the team was more than doubled according to the same ratio. This also gives an indication of the project's budget, as people cost far more than materials (roughly 90% of the budget). In addition, all physics teachers at the roughly twenty-five trial schools were paid for one or two hours per week in order to limit their teaching load and create time for extra preparation and attending the project's meetings/conferences.

Content selection – How were the contents of the curriculum selected? By whom and by which criteria? The contents of the curriculum were selected by the project team, in weak interaction with the trial school teachers.

The choice of contexts to be incorporated in the curricula ideally would be influenced by the differences in interest, abilities and plans for the future among students, and by long-term developments in society. The different needs of students could be met by choosing a variety of personal, social and scientific contexts (including nature, culture and technology). Linking physics to everyday life carries in itself the danger of the contents being initially timely, but not any more so a couple of years later. Therefore, we tried to choose the themes of our units taking note of long-term developments in society derived from surveys of literature and discussions with a few experts. Within the boundary condition of developing a physics curriculum this has led to a choice of issues on energy, traffic, electronics, armament, space travel, high-energy physics research etc. However, the choice of contexts for the units was not a completely free one. First of all we had to consider the existing nation-wide examination programmes. Although the project's task was to modernise and update physics curricula and to put forward proposals for changes in the examination programmes, one should not get too far away from what is customary within existing physics education. Being innovative in the field of curriculum development is a good thing, but adoption and implementation of the innovative materials by the teachers must remain feasible. So, the choice of themes and basic questions for the units carries in itself the character of a compromise between desirability and feasibility, requiring a thinking to and fro between contexts and physics contents.

Also at the level of a specific unit there were some problems with respect to the selection of contents: abundance of aspects and weak coherence of the units. Most themes encompass very complicated problems or large areas of knowledge, and boundaries with other subjects are sometimes vague. Trying to aim at completeness will be very confusing for students and teachers, and there is a danger of non-physical aspects dominating a unit. Using the earlier mentioned instrument of the basic question for a unit has been helpful in avoiding the abundance of aspects, and has even been more helpful in strengthening the coherence of the units. The main criterion for the selection of physics content at the unit level thus became the specific contribution physics could make to develop an insight into the theme. This has led to a reduction and an extension of physics content as compared to the existing examination programmes. However, also this selection process was a rather intuitive and pragmatic one. We had to reckon with 'outside pressures', for example from the school inspectorate, to keep standards high (that is, the standards of traditional teaching). Again, in many cases a compromise between the level of concept development necessary for dealing with practical situations in society and the standard level of concept development in the traditional curricula had to be reached. This means that the intention of introducing physics content on a 'need to know' basis (in the light of finally being able to answer the basic question for a unit) could not always consequently be carried out.

One problem, however, could not be solved by looking for a compromise. Generally the degree of versatility students reach in applying the concepts, laws and models in different contexts is low: concepts developed within one specific context are not automatically used by students when solving problems in another – known or unknown – context. For lower and average ability streams this limited transfer can be accepted to a large extent, because key concepts from the fields of energy and mechanics, for example, appear in a number of units in different contexts. But this is not enough for students in the pre-university stream. A solution we found for this problem was the introduction of so-called systematic units in combination with the thematic (context-based) units. In such a systematic unit concepts developed earlier in a number of thematic units are linked and defined more sharply in order to give students insight into the systematic structure of physics as a discipline. Mathematical expressions of concepts and relationships are much more sophisticated and prominent (as compared to the thematic units) in order to widen their applicability in a variety of different contexts.

Teaching methodology – Does the curriculum imply any particular teaching methodology? No, not really, although... Compared to the traditional curricula, the PLON curricula required more practicals (in the basic knowledge and skills part of the units) and more open-ended investigations (in the optional part of the units) including reporting by students and whole class discussions. This was certainly new for most of the teachers. One of the difficulties they encountered was getting used to the fact that part of the time different groups of students were working on different things: how to keep track of what they are doing? And of course the whole class discussions, mostly near the end of some units, about socio-scientific issues were also new and difficult (and therefore too often disregarded...).

Teacher-student interaction – Does the curriculum imply any particular teacher-student interaction? In relation with the changes in teaching methodology the 'distance' between teacher and students became smaller: less frontal classroom teaching, and more giving guidance to small groups of students. During the reporting sessions the students completely took over the teaching role of the teacher, with the teacher now in the role of observer with the task of giving adequate feedback on the students' presentations. Overall, however, the teaching could be characterised as being predominantly teacher directed.

Assessment – How are the learning outcomes assessed? Mostly through normal written tests, although the test questions were not always context-based and the tests mainly concentrated on the knowledge part of the units. In some cases teachers assessed the contents and quality of the students' oral reports during the reporting sessions. And in the end, of course, assessment took place by means of the nation-wide exams students had to take. In the context of the project's task of modernising and updating the existing physics curricula – with the accompanying changes in physics contents – these nation-wide exams were, with a considerable input from the project team and some trial school teachers, either completely (MAVO) or partly (HAVO) replaced by a new (context-based) exam.

4 Implementation

Strategy – What kind of strategy was involved for the implementation? The project's materials were only used at a limited number of roughly twenty-five trial schools, at which students were allowed to take the experimental PLON exams as indicated in the previous section. Administrators' fears of the number of schools opting for the PLON exams (and the teaching materials) getting 'out-of-hand' have put some serious restraints on the dissemination of the teaching materials. Non-trial schools could only occasionally replace a physics textbook chapter by a PLON unit. The implementation strategy was therefore directed at influencing (in line with the project's task) the discussion on the renewal of the examination programmes for physics, trying to incorporate as many PLON ideas regarding contents and contexts as possible. This would allow all schools in future to innovate their physics teaching. This, however, was beyond the scope of the project.

Limiting/facilitating factors – Which were the limiting or facilitating factors? With respect to implementation the limiting factor was, of course, the already mentioned limitation of the number of trial schools allowed to take the experimental PLON exams. However, the possibility of having 'our own exam' created the freedom for the project team and the trial school teachers to experiment, thus facilitating the innovation. This, however, has also led to a certain kind of fencing off from the larger community of physics teachers, certainly in the early years of the project. Publications about the project's teaching materials and evaluation results were almost non-existent at that time, partly because it was thought their use would be limited to those already involved, partly because we didn't like to provide tools to those who would love to abort PLON ideas before they were mature. Many of PLON's best ideas started rather immature and it often took several tries to get them in a proper form. In later years, this policy was changed considerably, but then part of the physics teacher community felt more or less overtaken, especially when it became clear that experiences within the project would be going to influence examination programmes. So, a kind of short-term dilemma: space for experimentation versus communication about innovation. From the viewpoint of longer term implementation the strong point of the project was the combination of development, research and policy-making. Development of curriculum ideas and teaching materials interacted with evaluation of classroom practice, and both elements could be used productively for writing up proposals for changes in the examination programmes and exams that over time would change physics education – at least to some extent. At this point the project's influence was limited, as decisions about these proposals were to be taken by an independent, government-installed committee.

Teacher education – Which role did teacher education play in the implementation? As a result of the above mentioned limiting factors teacher education did play a minor role in the implementation, if we do not consider the trial teachers. However, pre-service physics teacher education institutes were provided with the full set of materials and included the project in their courses. And, of course, after the decision making about the new examination programmes was done, all kinds of in-service courses were offered, either concentrating on the prescribed new physics contents or on alternative teaching methods. In general, however, most teachers had to rely on the commercially published new textbooks, the accessory traditional support materials (teacher's guides) and the user networks organised by the different educational publishers.

5 Evaluation

Research – How was the curriculum tested, evaluated, revised? A great deal of work was done in evaluating first versions of units, aimed at detecting 'infant diseases' such as management problems (equipment for practicals), unclarity of teaching aims (for students) and insecurity of teachers with new topics and teaching methods. Therefore the success of a unit could not be measured by its first version, but these first evaluations appeared to be of great use to collect ideas for revision, for teacher's guides and for teacher training. One could characterise this stage as more or less action-based (or small-e) evaluation.

A variety of methods was used for first version evaluation. Very important were the meetings with the teachers of the trial schools. After each unit we met and discussed the experiences. Teachers appeared to be very creative in finding solutions for the problems caused by the curriculum writers. They also challenged the writers on new ideas, so the latter were forced to explain clearly what they were aiming at. A second source of information was the questionnaires we presented to the students. Questions dealt with the instructiveness, usefulness, clarity and difficulty of the unit, their interest in various topics and their ideas about student activities. Finally we visited schools and observed what was going on in the classroom. Visiting schools, however, is very time-consuming, especially if one would like to observe all lessons in one class about one unit. Therefore, this source of information was used to a lesser extent.

Once the first versions were revised and the ‘infant diseases’ were cured a new round of evaluation started, now clearly focusing on students. A great deal of noise was now eliminated, so we tried to get a better insight into the impact on students’ learning at the level of specific units and on their attitudes towards various topics at the curriculum level. This could be considered as being more research-based and systematic (or big-E) evaluation. At the level of specific units it appeared that first version units highly criticised by students became quite appreciated by them in the second version as a result of better instructions for activities, proper introduction of main concepts, inclusion of examples of test questions etc. A second difference with first version evaluation results was a less significant difference between classes. This might be explained with the argument that the confusing first versions demanded more from the teachers in terms of clarification of what was expected and/or that teachers felt more at ease after having taught the unit before. In this new round of evaluation some attention was also paid to the learning outcomes in terms of the students’ mastering of traditional physics content for defending the educational innovations against their opponents.

In one of the studies at the curriculum level we asked students their opinion about the various units by means of a questionnaire at the end of the course (HAVO). The results show that students prefer some units more than others. Popular units are those which relate to daily life or specific interest areas of students, for instance the units about traffic, music, weather (boys) and ionising radiation (girls). Students seemed to be less fond of units which are either theoretical or technological, such as those about matter, energy, electronics and electrical machines (girls). On the other hand, the students’ judgements about the instructiveness of the units were more evenly distributed and did not seem to relate to the general preferences mentioned above. In general, students appreciated the physics lessons with PLON materials. They were especially positive about the student activities and the applied character of the physics. According to them these characteristics should get even more attention and especially students’ individual contribution to the lessons should be increased.

Evaluation of second version units resulted in some more questions in need of clarification. These issues, however, could not be addressed within the scope of the project. One of the issues was related to the project’s idea of broadening the aims of physics education. From the activity-based teaching and learning in relevant lifeworld contexts it was expected that students would experience the content taught as more relevant, and that they would be better able to understand and connect the concepts learned to their out-of-school world (Lijnse, 1995). Evaluation research regarding the PLON curricula at a later stage (beyond the project’s lifetime) has shown the first assumption to be reasonable. The second, however, has not appeared to be that simple. It appears that the PLON curricula do not differ from ‘traditional’ curricula as far as the students’ cognitive learning outcomes are concerned (Wierstra, 1990). This general outcome is confirmed by research on the teaching of radioactivity from a risk perspective in one of the PLON units (Eijkelhof, 1990). The same study also shows that it is difficult to have students use their acquired conceptual science knowledge in decision-making situations related to applications of ionising radiation, especially those situations in which students (might) have already formed an opinion. The box below outlines the research programme that has emerged over time after the official termination of the PLON project.

Research programme

These evaluation results concerning the PLON curricula are in line with the large body of science education research on students’ ‘common sense ideas’ and ‘alternative frameworks’ in science – and their resistance to change (White, 1987). They are also in line with the regrettably far smaller body of research into the students’ use of conceptual science knowledge in decision making. Conceptual science knowledge appears to play a subordinate role in decision making about socio-scientific issues (Fleming, 1986a; 1986b; 1987; Solomon, 1992; Ratcliffe, 1994; 1997). These findings might at first sight be explained by the ‘traditional’ character of the curricula, with decision making as a kind of loosely connected add-on. In such a case the conceptual science knowledge is not presented in a decision-making context, and students might then not recognise the applicability of this knowledge when at some later stage they are confronted with a decision-making situation. However, the research results concerning the PLON unit about ionising radiation show that an STS approach to science education in which the decision-making context is far more prominent from the start, does not help very much either in this respect. So, another explanation is required. In drawing the above conclusion about conceptual science knowledge playing a subordinate role in students’ decision making, it is assumed that students have indeed acquired this knowledge. Moreover, it is assumed that this (supposedly acquired) science knowledge is indeed relevant for the decision making at hand. Both assumptions might not be valid.

An early expression of these doubts can be found in the conclusion of the study concerning the PLON unit about ionising radiation: in order to improve the quality of teaching about science/technology-related social issues, there is a need to legitimise the teaching contents, to select the students’ ‘common sense ideas’ or ‘alternative frameworks’ to pay attention to, and to develop strategies to deal with these ideas or frameworks effectively – as the study showed that the unit did not change the students’ common sense ideas about ionising radiation very much and the learning outcomes did not very much differ from traditional physics teaching (Eijkelhof & Lijnse, 1988). Moreover, there is a need to investigate the effects of teaching on students’ decisions, on the way in which students arrive at their decisions, and on the quality of their arguments (Hofstein *et al*., 1988). In a somewhat more precise wording: there is a need to improve students’ acquisition of conceptual science knowledge and to scrutinise the match between this science knowledge and the decision-making situations it has to be applied to.

These remarks point at another weak point of the PLON project. The project has been able to draw a great deal of attention to alternative content and teaching methods for physics education. However, the project’s working area has been very wide: complete curricula have been developed for various ability streams in both junior and senior secondary education, a variety of aims was set and innovation regarded contents, methods and differentiation. As might have been predicted, width cannot be combined with great depth. The study already mentioned about the unit on ionising radiation was a first step in this direction of having a closer look at contents and learning.

The next step has been one of taking a far more detailed look at the teaching/learning process. In general ‘traditional’ science curricula as well as most STS curricula adopt a teaching/learning strategy of top-down transmission, without really taking into account what students already know, think and are interested in (Lijnse, 1995). Such teaching almost unavoidably results in a process of forced concept development, which may – at least partly – explain the often disappointing cognitive learning results in science education. This points at the necessity of an improved teaching/learning strategy that takes the students’ existing pre-knowledge and skills into account, and that provides them with a motive to extend these further in a specific direction. This reflects the adoption of the perspective of educational constructivism (Ogborn, 1997), combined with the idea of a problem-posing teaching/learning process with a backbone of developing content-related motives that drive the students learning process: a coherent sequence of teaching/learning activities designed on the basis of a profound knowledge of the students’ relevant pre-knowledge as being coherent and sensible (instead of being wrong) and using their knowledge productively (instead of immediately trying to change or replace it) in a social process of the teacher’s and students’ coming to understand each other (Klaassen, 1995; Klaassen & Lijnse, 1996) – *No dark sarcasm in the classroom*...

An essential element of such a teaching/learning process is to provide students with motives for starting and continuing their learning process. The combination of the students’ existing motive for learning and pre-knowledge about a specific topic should be used to induce in them a need for extending their knowledge. In a problem-posing teaching/learning process we aim at bringing the students in such a position that preferably they themselves, guided by the design of the teaching/learning activities, come to formulate this need for extending their knowledge. In other words: preferably the students themselves should pose the problem to be further investigated. As a consequence, throughout the ensuing process of solving the posed problem there should be ample opportunity for the students to put forward their interpretations of what has been learned, to be taken seriously and used productively by the teacher to drive the teaching/learning process farther. This process is then also guided by the students' own motives, knowledge and questions, so that they themselves frame the questions that drive their learning process – *Teachers leave the kids alone*...

These ideas about a problem-posing teaching/learning process were introduced and elaborated in a developmental research project for the topic of radioactivity (Klaassen, 1995), followed by comparable projects about the introduction of an initial particle model (Vollebregt, 1998) and decision making about the waste issue (Kortland, 2001). These studies represent the current research programme on so-called 'didactical structures' for the teaching/learning of specific topics and – based on those – more general ones at our institute (Lijnse, 2000).

Impact – Did the curriculum have an effect on science teaching? The box above has indicated the impact of the PLON project on our current research (including development of teaching materials for research purposes). But what about main-line physics teaching? In the years beyond 1986 the examination programmes have clearly become more context- and skills-oriented, more for junior than for senior physics education, more for the lower ability streams than for the higher ability streams, and in differing degree of detail. Consequently the character of the nation-wide examinations for the various streams has changed in the same direction, and also infusion of PLON ideas in traditional physics textbooks is visible – again to quite different degree. More recent changes concern the inclusion of technology and the associated skill of designing, independent working/learning by students and the inclusion of open-ended investigations as part of the exam. Physics in context appears to be 'accepted' – although not by everyone. Recently, theoretical physicists started complaining about the character of the examinations (and implicitly about the underlying examination programmes) in which the fascination of 'pure physics' was lost in the muddle of 'applications'.

But what happened to the PLON materials in the meantime? Collecting dust? In some ways, yes... Not all proposals did survive the government-installed programme committee. Therefore it was decided to start adapting the PLON materials into a series of commercially published physics textbooks under the umbrella of the PLON Association – an association of teachers and curriculum developers on a voluntary basis with the aim of keeping the PLON ideas alive and kicking through rewriting the materials on a free-lance basis. Although at this moment also this association has ceased to exist, the third generation of 'PLON-materials' in the form of a commercially published textbook is relatively widely used (about 25% market share). A textbook in which the integration of physics contents and contexts is less dominant, but still clearly present. The physics content and its everyday life applications (the personal, technological and scientific contexts) are now presented separately, but clearly connected throughout a chapter. This move away from the original PLON idea of complete integration appeared to be necessary for commercial reasons, as teachers and students were asking for more clarity about what physics contents should be learned for the tests and exams. As compared to the other commercially available textbooks, the context-based approach to physics is elaborated in a more pervasive and coherent way, with more attention paid to skills development, to students' pre-knowledge and associated teaching/learning strategies, and to providing support for the independent working/learning of students.

Conclusion

Over the years, the PLON project has produced a wealth of ideas and accessory teaching materials, still influencing Dutch mainstream physics teaching practice – be it to different degrees, depending on the view of schools and teachers on what constitutes attractive and effective teaching and learning. There is, however, still one issue that has not been addressed so far: would we do differently, if we had a second chance? A question difficult to answer, but no... probably not, at least as far as the ideas about the aims of physics education and the context-based character of the curricula are concerned – although these ideas could, of course, always be made more articulate and more consequently applied in the development process. Also the idea of a central co-ordinating project team co-operating with teachers would certainly survive a scrutiny of PLON's strengths and weaknesses, as well as the idea of combining development, research and policy-making. I'm less sure whether the idea of developing full courses would survive such scrutiny. Probably, with hindsight, the choice would be one of depth instead of width – more emphasis on research and development (or developmental research) with a focus on research-based decisions about physics contents and contexts and on designing adequate teaching/learning processes (including exemplary teaching materials) for effectively developing students' knowledge and skills as outlined earlier under the heading of research programme. And this would certainly include more support in terms of coaching for teachers using, adapting and/or expanding these ideas in their own classroom practice.

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Appendix

PLON teaching units for secondary physics education

Grade	All ability streams
8	A first exploration in physics
	Men and metals
	Working with water
	Living in air
	Ice, water, steam
9	Bridges
	Seeing movements
	Colour and light
	Electrical circuits
	Reproducing sound
	Water for Tanzania
	Energy in our homes
	Energy in the future

	Lower ability stream MAVO	Average ability stream HAVO	Pre-university stream VWO
10	Forces	Comparing	The human body
	Traffic and safety	Weather changes	Music
	Stop or keep moving	Music	Traffic
	Heating and insulating	Traffic	Motion*
	Switching and controlling	Electrical machines	The weather
	Machines and energy	Energy and quality	
	Nuclear arms and/or security		
	Review for final exam		
11		Matter	Energy
		Light sources	Sports
		Ionising radiation	Electric motors
		Electronics	Work and energy*
		Review for final exam	Automation
12			Physics around 1900
			Particles in fields*
			Ionising radiation
			Satellites

* systematic units

All units consist of a student's textbook, a teacher's guide and a technician's manual. All course material is written in Dutch. Some units – *Bridges*, *Water for Tanzania*, *Traffic*, *Light Sources* and *Ionising radiation* – were translated in English.