A Thematic Physics Curriculum: A Balance Between Contradictory Curriculum Forces

PIET L. LIJNSE, KOOS KORTLAND, HARRIE M. C. EIJKELHOF, DIK VAN GENDEREN, AND HERMAN P. HOOYMAYERS
Centre for Science and Mathematics Education, University of Utrecht, The Netherlands

Introduction

Over the past twenty five years a number of trends in physics education at the secondary level have developed. These include (1) more emphasis on technological and social aspects of physics, (2) a more child-oriented and activity-based classroom and (3) more attention to student-relevance, and (4) greater focus on the affective and social aspects of learning. There is also the "back to the basics" reaction to these trends.

In recent years the impetus to broaden the aims of physics education seems to have grown stronger (Aikenhead, 1985; Yager, 1985): physics education should not only focus on the teaching of physics as a discipline in order to prepare a relatively small number of students for becoming an academic scientist, but it should also pay ample attention to the technological and social aspects of science in order to prepare all students for living in a technologically developing, democratic society.

The purpose of this article is to illustrate what such a change might look like. We describe in some detail a Dutch thematic physics curriculum recently developed for the average academic secondary student grades 10–11 (Lijnse and Hooymayers, 1988). Also we will make some remarks about the way in which this curriculum has been expanded for use in the specialized pre-university stream of secondary education, grades 10–12. Both curricula have been developed by PLON (a Dutch acronym for *Physics Curriculum Development Project*). This project has sought to modernize and update physics teaching, and to prepare proposals for changes in the nationwide examination syllabi.

Before describing the PLON curriculum itself, we outline the main societal and educational trends that influenced the project team.

Trends

Curriculum Waves

Physics teaching in the Netherlands in the early sixties was what many of us now call highly academic. It had much chalk and talk, very few classroom demonstra-

Science Education 74(1): 95–103 (1990)

CCC 0036-8326/90/010095–09$04.00

tions, and almost no activities for the students. The syllabus did not include recent developments in physics and it made few connections to technology or everyday life situations.

Much has happened since then. A curriculum wave broke out and flooded large parts of the world. In the United States *PSSC* (PSSC-Physics, 1960) was developed with its emphasis on the structure of the discipline, with a more updated syllabus and, as well, with ample attention to student activities. Discovery learning, be it guided or not, received even more attention when the English *Nuffield* materials (Nuffield 0-level Physics, 1966) became available. The "enquiring classroom" emerged. This encouraged a shift from teaching concepts and structure alone, to teaching scientific thinking skills as well. Quite another way of teaching inquiry was advocated by the American *Project Physics* materials (Harvard Project Physics, 1971). Science, as a human activity, was placed into an historical, philosophical and social perspective.

This was the educational climate which gave rise to PLON. It profited from the wealth of innovative ideas, particularly the emphasis on relating physics contents to the local environment of the students and to the technology surrounding them.

As the flood of curriculum reform inundated science education, the political and economic situation changed. The limits to economic growth in the sixties became gradually visible; environmental problems showed up. The tension between economic and environmental considerations led to a growing intensity of public debate, at first focussing on our energy future but very soon extending towards a more general discussion on the impact of scientific and technological developments on society. This societal change led to a growing pressure, both from within and from outside the education system, to broaden the aims of (physics) education. It was thought that students should acquire a better understanding of this public debate and to acquire an ability to take part in a more informed and thoughtful way. This gave rise to a new curriculum wave. Special courses on the social aspects of physics and technology were developed; for example, *Science in Society* (Lewis, 1981), *Physics in Society* (Eijkelhof, Boeker, Raat and Wijnbeek, 1981) and *Science in a Social Context* (Solomon, 1983).

The curricula for senior secondary education developed by PLON in more recent years have been influenced by these developments (Eijkelhof and Kortland, 1988). However, the problem was to find a reasonable balance among all the trends in science education. PLON sought to be conceptually updated. It wanted a more activity based and student involved way of teaching and learning. PLON planned more emphasis on the development of scientific thinking skills, more emphasis on science as a human endeavour, and more emphasis on the interactions of science, technology and society.

Curriculum Considerations

The PLON team was not the only group struggling with this issue, as can be seen in policy documents from the *Association for Science Education* in the United Kingdom (ASE, 1981), the *National Science Teachers Association* in the United States (NSTA, 1982) and the *Science Council of Canada* (SCC, 1984). These documents suggest that physics teaching should move away from the aims of teaching the pure knowledge and skills of physics. But in what direction should physics teaching move? In our opinion the most important aspects to this question can be examined from three perspectives: physics, students and teachers.

From the perspective of academic physics, changes to physics teaching would mean changing one's view of what physics as a science is all about. A new curriculum should try, on the one hand, to give an intellectually adequate and up to date image of physics in its broadest sense, as it plays a role in pure and applied science, technology and society. Physics should deal with the structure of matter and the cosmos as well as with natural phenomena and living beings, with scientific as well as with technological and social issues. It should be taught as a human activity with a certain cultural, historical, and philosophical, ethical and social understanding. Students should be actively involved in their lessons and should reflect upon the human aspects of physics. On the other hand a new curriculum should ask which knowledge and skills may be expected to be relevant for children growing up in a technological democratic society, preparing themselves to play a role as a consumer of science and technology. Such a role requires a responsible citizen dealing with value-related decision making processes in society at large.

From the perspective of students, the curriculum should be interesting, relevant and meaningful to all, girls as well as boys. It should take into account possible differences in cultural and social background. It should be structured in a way that provides sufficient opportunities for children to follow and become aware of their own interests, working styles and present and future possibilities.

From the perspective of teachers, the curriculum should give them certain opportunities to follow their own interests and preferred ways of teaching. It should enable them to try out new educational developments and to make certain adaptations according to local and actual needs.

These rather abstract considerations gave rise to PLON. Part of the PLON-work is described in the next section, to show how we tried to reach a balance between all these, and at certain points, seemingly contradictory curriculum aspects.

A Thematic Physics Curriculum

The PLON curriculum described is generally meant for students taking academic secondary education in physics, grades 10–11. This program prepares students for higher professional training. Near the end of this section we will make some short remarks about the way this curriculum has been expanded for use in a more specialized pre-university stream of secondary education, grades 10–12.

In grades 10–11 the students are generally 15 to 18 years old. They have been taught physics during two previous years as part of the compulsory set of school subjects. In grades 10–11, however, physics is no longer obligatory. About 50% of the boys and 15% of the girls choose physics as an optional subject in these grades.

General Outline

A main characteristic of the curriculum is its thematic structure. It consists of ten thematic units, each of them written around a certain central theme. Titles of the units are: *Comparing, Weather Changes, Music, Traffic, Electrical Machines, Energy and Quality, Matter, Light Sources, Ionizing Radiation* and *Electronics*.[1]

As these titles suggest, PLON offers a thematic approach. Such a thematic structure has the considerable advantage of introducing a fair amount of flexibility into the curriculum and it relates the knowledge of physics to an everyday life context. Such a context is not only recognizable for students, but it may also be experienced by them as relevant and meaningful.

In order to achieve this relevance and flexibility, heavy demands are put on the themes actually chosen. The choices above have been made keeping in mind four different perspectives. What knowledge from the realms of physics could be useful for:

1. use in everyday life,
2. presenting an authentic view of physics,
3. triggering the various interests among students,
4. preparing students for further education.

Nevertheless a certain amount of arbitrariness has been unavoidable in the final selection of the themes. Also the existing physics syllabus for the nationwide examination put some restraints on the freedom to choose the themes. Although the project's task was to modernize and update physics teaching, the number of changes in the traditional physics content could not be too great. PLON had to be eventually accepted by physics teachers in order to be implemented into Dutch schools.

The Structure of a Thematic Unit

As indicated in Figure 1, each unit begins with an *orientation* on the relationship between a specific physics domain and the everyday life context. An orientation describes how this part of physics might be helpful for using technological device, for making a consumer decision and/or for understanding a socioscientific issue. This relationship is reflected in a central question which sets the scene for a unit. The question also functions as a criterion for selecting the content and skills for the unit. Ideally this central question should have relevance for students. It should be broad enough to meet the differences in interests and should provide the possibility of being translated into a variety of suitable student activities.

The orientation is followed by a section in which some *basic knowledge and skills* concerning the topic are taught, preferably in the form of various student activities which stimulate independent learning in small groups. For instance, in the unit *Weather Changes* the central question can be described as: "Which factors determine the weather picture? How do these factors influence weather changes? How

[1] All PLON teaching units are written in Dutch, but two of the units described in this article have been translated into English and adapted for use in other countries. Glen S. Aikenhead has taken care of the translation and adaption of the unit *Light Sources* for trials in Canada, while Peter J. Fensham has done the same with the unit *Ionizing Radiation* for Australia.

For information on the availability of both units, contact Harrie Eijkelhof or Koos Kortland, Centre for Science and Mathematics Education, p.o. box 80.008, 3508 TA Utrecht, the Netherlands, tel. 030-531179/532717.

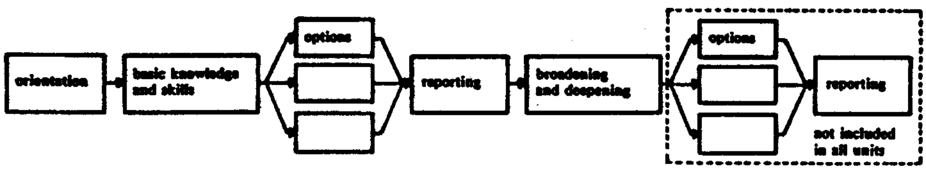

Figure 1. General format of a thematic teaching unit.

can a (reliable) weatherforecast be based on such information?" In this case, methods of measuring temperature, air pressure, humidity, wind-velocity and direction as well as the interpretation of simple weathercharts and satellite photographs, are considered as basic knowledge and skills.

After studying this compulsory part of a unit, students start working on different *options* in parallel groups. The learning experiences of the parallel working groups are to a large extent complementary to each other, and the essentials of all of them are required in the next part of the unit. Therefore, these optional parts require an exchange of ideas between the various groups of students. This occurs in a *reporting* session. In the unit *Weather Changes* these parallel options are on clouds and cloud formation, on precipitation, and on fronts and high/low pressure areas.

Together with basic knowledge and skills, the learning experiences in these optional parts are used to discuss questions dealing with topics such as: which methods a weatherforecast is being made, how such a forecast has to be interpreted and what to expect from its reliability. These questions require students to integrate their ideas. Students therefore *broaden and deepen* their knowledge and skills. But these questions also refer to the central question of the unit, as stated in the orientation. In this part of the unit it should become clear to the students that their learning experiences help in finding answers to the central question.

Optional sections at the end of a unit have the objective of meeting different student interest's with regard to their preference for a more scientific, technological or social approach, or with respect to their plans for further education or employment. Reporting on learning experiences and activities in this case is more informal.

PLON units foster in students, not only a responsibility for their own learning, but also a responsibility for the learning of their fellow students. All students have to share some essential learning outcomes. In this way an active and more concerned learning environment is encouraged. The PLON unit model also allows students to engage in a wide variety of learning activities which may even involve out-of-school activities, in order to meet not only differences in interests but also in working styles and capabilities.

Content of the Units

The introductory unit is called *Comparing*. The central question of this unit is: "How does one make fair comparisons?" This is a basic skill, relevant in both research and everyday life situations. It involves choosing suitable quantities and appropriate methods to measure them. Students first encounter these choices in an example about the energy use of washing machines. Subsequently they practice the skill of comparing products and systems, such as heat insulation in houses, electrical circuitry at home, and safety gadgets for bicycles.

Weather Changes, the second unit was described above.

Music is the third unit. Its central question is: "What objective factors determine the character and quality of music, and how are these factors subjectively perceived?" The unit deals with the physics topic of vibration and waves, in connection with the dynamic characteristics of musical instruments, audio equipment (e.g. frequency response) and the human hearing system. In addition, aspects of acoustics (absorption, reflection and reverberation, resonance) in rooms and concert halls are considered. By relating those findings to each other, the concept "quality of music," which at first seems totally subjective, acquires an objective meaning as well. The topics have relevance in everyday life situations. This relevance is enhanced the more students are encouraged to explore their own instruments, audio equipment, voices and ears. The optional part at the end of the unit has report writing as a central skill.

Traffic deals with the following central question: "Which factors are important from a physics perspective for safety and fuel economy in traffic situations?." It tackles this question by concentrating on the forces that actually control motion in traffic situations. After an historical introduction in which the development of public transport is described briefly in relation to technological progress, students work on "real life" experiments (with bicycles and mopeds). Students also work on model experiments (with toy cars in a small windtunnel, ship models) and on analysing slow motion movies of car collisions. The unit deals with such concepts as force, mass, speed, acceleration, work and the laws describing their relationships. These concepts are used to find answers to (1) how the use of seat belts and crash helmets help in improving traffic safety, (2) how to select a safe driving speed and, (3) how to save fuel expenses (and the environment) by choosing a certain type of car and driving speed. The optional part at the end of the unit deals with the way a scientific or technological investigaton can be set up.

Electrical Machines is more a technological unit than a scientific unit. It deals with the basics of electric motors and power generators, as well as with measuring and comparing characteristic properties of various types of electrical machines. This culminates in the problem of choosing an appropriate electrical machine for a specific task. The unit uses this knowledge in considering simple and safe repairs of electrical machines at home. The related topics of electricity and magnetism form the physics core of this unit.

Energy and Quality, the next unit and the last one for grade 10 concentrates on "How to use knowledge of physics and technology in "being wise" with energy, both at home and in society at large". This unit has a strong social issue character. It discusses the quality of energy in view of the quality of society. Much attention is given to energy conversions, efficiency, and the degradation of energy. At the end of the unit students must decide on an appropriate energy system, either at home or on a local or national scale.

Matter, the first unit for grade 11, is quite different. It concentrates on: "What ideas about the structure of matter have been hypothesized from the Greeks to the present? What is the current research in this field? Why and how are physicists actually working in it?." The unit describes the history of atomic theory up to the present quark model. Traditional physics topics include the characteristics of electric and magnetic force fields and the relationship between these fields and the motion of fundamental particles. The unit clarifies the experiments undertaken by physicists today as they unravel the structure of matter. Against this conceptual background, the human side of physics is illustrated by short biographies of four famous physicists (J. J. Thomson, Rutherford, Röntgen and Curie) which students read, compare and discuss. Developments in fundamental particle physics have gone from "small physics" to "big physics." Thus the unit gives students an idea of the motivation of physicists as well as raises the question whether this research is really worth the huge sums of money it takes.

The unit *Light Sources* begins with the historical importance of electrical light in changing our daily life. Next the unit concentrates on the construction of light sources as a technological process of optimalisation. Different light sources (incandescent lamps, discharge tubes) are used for different purposes because of different characteristics. Their construction and use involve weighing their economic, esthetic, physical and technological aspects. New developments in physics and technology also lead to new light sources such as high pressure lamps, lasers, SL-lamps. Atomic theory is used to explain the different characteristics of light sources and to clarify the development and construction of new light sources.

Ionizing Radiation deals with a much more problematic topic. It centers on the question of the acceptability of risks of ionizing radiation. After dealing with the nature of this kind of radiation, its sources and ways of measurement, the possible effects of ionizing radiation on the human body are described. Special attention is given to the risks and benefits of ionizing radiation in medical applications, nuclear energy and nuclear arms. At the end of the unit students have to concentrate on one of these applications from the point of view of personal and social risk evaluation, in order to reach a reasoned opinion on its risk-acceptability.

Finally, the unit *Electronics* deals with the interrelation of physics, technology and society, particularly the recent historical developments in this field. Electronics deals with telecommunication, data handling and automation. Coding and decoding of information plays a central role. This is first described by the use of simple electronic components and circuits, including the transistor as a switch. Miniaturization, made possible by semiconductor techniques, has brought data handling processes into the hands of everyone. Students experiment with digital transmitters and receivers, automatic measuring systems and a computer steered electromotor (as a component of a programmable industrial robot). The work on such systems ends with a final discussion on the question whether an electronic revolution like the present one is and/or should be manageable in a society like ours.

Thematic and Systematic Units

Our curriculum was expanded for use in the specialized pre-university stream of Dutch secondary physics education in grades 10–12. The biggest problem which arose was the different character of concept learning between a thematic unit and the traditional structure-of-physics unit employed in the specialized pre-university stream. The difference in character can be described as the difference between inclusive and exclusive concepts (Schaefer, 1979). In the thematic PLON units, concepts are taught mainly in an inclusive way, which means that they are taught in direct connection with the contextual situations in which they have to function. Thus, these contextual elements are part of the concept and are not to be treated separately. The specialized pre-university's exclusive teaching of concepts separates concepts from their use, because the emphasis is put on the formal relationships and logical structure. One could say that in the thematic PLON curriculum we have to some extent shifted the emphasis away from the generality and coherence of the theoretical knowledge of physics as a discipline, towards the functionality and relevance of this knowledge in everyday life.

In order to meet the expectations of the specialized pre-university stream, the PLON thematic units are supplemented with so-called *systematic units* (Dekker and Van der Valk, 1986). In a systematic unit, concepts developed earlier in one or a number of thematic units act as a starting point for "exclusive" instruction. Concepts from different units are linked up and defined more sharply in order to give students insight into the systematic structure of physics. This is done mainly for the topics of force and motion, energy and work, and gravitational, electric and magnetic force-fields. Mathematical expressions of concepts and relationships between concepts are more sophisticated and prominent (as compared to the thematic units) in order to widen their applicability in a variety of different contexts. As well more attention is paid to the development of problem solving abilities.

Some Remarks About the Curricula

Our brief description of the PLON units is insufficient to communicate a complete image of the curricula. Nevertheless it may suceed in giving some idea of (1) how the PLON teaching materials relate to the curriculum considerations stated earlier in this article, (2) what these curriculum aims are, and, (3) how those aims are put into practice.

Of course one might wonder if we expect too much from our innovations in physics education. What actually results from such high phrases as "physics education should contribute to the preparation of students for their (future) life role as responsible citizens"? Much more experience, curriculum development, teacher training and research is needed before this question can be addressed empirically to any extent (Eijkelhof and Lijnse, 1988). In spite of the possibly large gap between the ideal and the reality, such aims offer perfectly valid and useable guidelines for educational innovations. These innovations lead to significant differences in curricula and teaching practice. In the end it is always a matter of choice of educational philosophy, based on scientific, psychological, pedagogical and social considerations. The PLON units sought to find the "right" balance among all the aims that are worthy of pursuit, a balance that will look different for different countries with different educational systems and for different age groups and ability levels of students.

PLON units offer an example of how physics education for the average academic student might be changed in order to incorporate the new and broader aims that society asks for, without loosing its identity as an education in physics.

References

Aikenhead, G. S. (1985). Science curricula and social responsibility. In R. Bybee (Ed.), *Science-technology-society*. 1985 Yearbook National Science Teachers Association. Washington, DC: National Science Teachers Association.

ASE (1981). *Education through science*. Hatfield: Association for Science Education.

Dekker, J. A., & Van der Valk, A. E. (1986). Pre-university physics presented in a thematic and systematic way—experiences with a Dutch curriculum development project. *European Journal of Science Education, 8*(2), 145–153.

Eijkelhof, H. M. C., Boeker, E., Raat, J. H., & Wijnbeek, N. J. (1981). *Physics in society*. Amsterdam: VU Boekhandel.

Eijkelhof, H. M. C., & Kortland, J. (1988). Broadening the aims of physics education—experiences in the PLON project. In P. J. Fensham (Ed.), *Development and dilemmas in science education*. London/Philadelphia, PA: The Falmer Press.

Eijkelhof, H. M. C., & Lijnse, P. L. (1988). The role of research and development to improve STS-education: experiences from the PLON project. *International Journal of Science Education, 10*(4), 464–474.

Harvard Project Physics (1971). New York, NY: Holt, Rinehart and Winston.

Lewis, J. (1981). *Science in society*. London: Heinemann Educational Books Ltd.

Lijnse, P. L., & Hooymayers, H. P. (1988). Past and present issues in Dutch secondary physics education. *Physics Education, 23*(3), 173–179.

NSTA (1982). Science-Technology-Society: science education for the 1980's—an NSTA position statement. Washington, DC: National Science Teachers Association.

Nuffield 0-level Physics (1966). London: Longman/Penguin Books.

PSSC-Physics (1960). Boston, Mass: Heath and Company.

SCC (1984). *Science for every student: educating Canadians for tomorrow's world*. Ottawa: Science Council of Canada.

Schaefer, G. (1979). Cognitive formation in biology: the concept 'growth'. *European Journal of Science Education, 1*(1), 87–101.

Solomon, J. (1983). *Science in a social context*. Oxford: Basil Blackwell.

Yager, R. E. & Hofstein, A. (1985). Defining enlarged boundaries for school science. *European Journal of Science Education, 7*(4), 345–352.

Accepted for publication 10 May 1989