J. Kortland

A Problem-Posing Approach to Teaching Decision Making about the Waste Issue

J. Kortland

A problem-posing approach to teaching decision making about the waste issue – Utrecht: Cdβ Press – Freudenthal Institute for science and mathematics education (FIsme), Utrecht University – FIsme series on Research in Science Education; nr. 37; 2001.

ISBN 90-73346-44-4

Key words: decision making / waste / physics and chemistry / lower secondary education

PhD Thesis, Utrecht University, Faculty of Physics and Astronomy

Promotor: Prof.dr. P.L. Lijnse
Co-promotor: Dr. C.W.J.M. Klaassen

The full list of publications in the FIsme series on Research in Science Education can be found at the FIsme website: http://www.cdbeta.uu.nl > English > Research > FIsme series.

Contents

1 Introduction

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
The Wall, 1979

1.1 Motive

This study deals with students' *decision making* in science/technology-related social issues. And more specific: this study deals with the *teaching and learning* of decision making on these issues in junior secondary science education. Why this topic?

The motive for starting the subject-specific didactical research to be described in this study can be found in a mix of the following three movements in Dutch secondary science education over the past decades: the emergence of *science, technology and society education* (STS education) and – either as a component of STS education or as a 'subject' on its own – *environmental education*, a growing perceived importance of and emphasis on students' skills such as investigating, designing, problem solving and decision making, and an attempt at applying constructivist ideas about teaching and learning to classroom practice. Or, in other words: a shift of emphasis with respect to *contents*, *skills* and *teaching/learning process* – a shift of emphasis towards science contents in an everyday life context, towards skills to use these contents productively, and towards a teaching/learning process to reach these aims effectively. The shift of emphasis with respect to contents and skills is clearly visible in the current and proposed examination programmes and in the textbooks for science subjects in junior as well as senior secondary education. The shift of emphasis with respect to the teaching/learning process is still almost invisible in classroom practice, and is only just beginning to permeate the domain of subject-specific didactical research.

The combination of these three movements has triggered the research reported in this study. In sections 1.2 and 1.3 of this introductory chapter the shifts of emphasis

in contents, skills and teaching/learning process are briefly explored. This exploration will identify the issues providing the motive for this study, and will be concluded in section 1.4 with the formulation of its general research question.

1.2 Contents and skills: a shift of emphasis

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* …

STS 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, 1988; 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 1.3.

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 detri-

mental 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. An expression of this shift of curriculum emphasis are courses such as *Patterns* (Schools Council Integrated Science Project, 1973), *Science in Society* (Lewis, 1981), *SISCON-in-Schools* (Solomon, 1983), *Chemcom: Chemistry in the Community* (American Chemical Society, 1988), *CEPUP: Chemical Education for Public Understanding Program* (Thier & Hill, 1988) and *LoRST: Logical Reasoning in Science and Technology* (Aikenhead, 1991), and infusion materials such as *SATIS: Science and Technology in Society* (Hunt, 1988). Also part of this international curriculum movement are the science courses developed by the Dutch *Physics Curriculum Development Project* (PLON) between 1972 and 1986 for junior and senior secondary physics education (grades 7-12). This project was based at the *Department of Physics Education*, one of the constituting parties of the later *Centre for Science and Mathematics Education* (Cdβ) at Utrecht University. The Dutch Ministry of Education and Sciences financed the project with the intention of developing proposals for updating and modernising the existing physics curricula.

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 …*

Environmental education

In STS education *environmental issues* have been prominent from the start (Bybee & Mau, 1986; Zoller, 1987; Fensham, 1988). The Dutch government's attempt to create public support for its environmental policy in the 1980s provided a new opportunity for further developing this STS component, now under the heading of *environmental education*.

As a kind of follow-up to the PLON project the *Centre for Science and Mathematics Education* has been substantially involved in an environmental education curriculum development project between 1986 and 1991, limited to junior secondary education (grades 7-9) and the school subjects biology, geography, chemistry and physics. This NME-VO project was financed by the Dutch Ministries of Education, Environment and Agriculture. These three ministries were convinced that environmental education should get a distinct place within secondary education, not as a new subject on its own, but by making it an explicit cross-curricular issue for the existing school subjects mentioned above. One of the tasks of the project was to develop a *core curriculum*, proposing a common aim and a common conceptual framework for environmental education in the different school subjects (Pieters, 1990). In this core curriculum it is assumed that education should help students to understand environmental issues and to make thoughtful decisions about their environmental behaviour in everyday life. Or, in the precise wording of the core curriculum's common aim: *pupils acquire knowledge and skills which enable them, in their thinking and acting, to take into account a sustainable development of the relationship between man and the environment*. This common aim has two components. The first component is acquiring knowledge about a sustainable development of the relationship between man and the environment: the problems in that relationship, and the solutions for those problems in view of a sustainable development. The second component is the skill to apply the acquired knowledge to *decision making* in everyday life. This second component sort of legitimises the first component: in order to make a thoughtful decision, one will have to be well informed.

The teaching/learning units developed by the NME-VO project were meant for co-ordinated teaching in a combination of two up till four of the school subjects. This could be seen as an expression of the cross-curricular character of the environmental issues. Comparable to the PLON units it was tried to deal with the basic subject-specific concepts and skills in a personal and social context. Despite the government's 'hidden agenda' of creating public support for its environmental policy, the project's position regarding students' decision making was again one of individual responsibility of the student. However, more than in the PLON units it was tried to help the students in their decision making by structuring the decision-making process (Kortland, 1989; de Jager & van der Loo, 1990). This common stepwise decision-making procedure was left implicit to the students. It was only, and still tentatively, included in the project's core curriculum in rather general terms.

Research

The emergence of STS education (including environmental education) in Dutch secondary education through both of the above mentioned curriculum development projects 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. However, the question of which traditional science content was supposed to facilitate a better understanding of which issues was answered in a rather pragmatic and intuitive way. The little research there was in both curriculum development projects mainly focused on the students' appreciation of curriculum elements for revision purposes, and on the students' mastering of traditional science content for defending the educational innovations against their opponents.

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 life-world 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). Evaluation research regarding the PLON curricula at a later stage 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.

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). 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 (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. Tackling these issues becomes even more pressing as ideas about STS education have already started influencing the Dutch nation-wide attainment targets for secondary science education a couple of years ago.

Attainment targets

The curriculum development projects mentioned above have left their marks on the subsequent revisions of the nation-wide attainment targets for the science subjects, although for junior secondary education more distinctly than for senior secondary education. As far as science content is concerned, the idea of *science in context* seems to be rather generally accepted through its inclusion in the attainment targets for junior as well as senior science education (CHE, 1990; WEN, 1988). These attainment targets also start to show an increased emphasis on the development of students' skills, such as performing experimental research, searching and processing

information (information and communication technology), designing artefacts (technology), problem solving, etc. In this skills domain too, the idea of science as one of the tools for *decision making* is overtly expressed – be it only in the attainment targets at the junior secondary level.

The attainment targets for physical science in Dutch junior secondary education (grades 7-9, 12-15 year-old students), in operation since 1993, mention an understanding of some *environmental issues*: water, waste, energy and noise – with a focus on a balance between environmental impact (depletion of resources and pollution of soil, water and air) and measures to counter this impact. Related to these attainment targets the programme refers to *decision making*: students will be(come) able to *present an argued point of view* in a situation of choice between alternatives (CHE, 1990). This puts at least a part of the Dutch physical science curriculum under the umbrella of STS education, in which decision making is one of the consistently emphasised student skills (e.g., Aikenhead, 1994).

In this new programme the influence of the earlier curriculum development work in environmental education for the science subjects concerning knowledge about a sustainable development of the man-environment relationship as well as decision making is clearly visible. But the programme reflects the same weakness as the above mentioned core curriculum for environmental education: in the attainment target dealing with decision making any indication of how these words (present an argued point of view) might be interpreted is lacking. The interpretation of this attainment target is left to textbook authors, teachers and examination experts. As decision making is something new for physical science education, this situation might in classroom practice easily lead to a rather minimal operationalisation of having the students state that in making a decision one has 'to take the environment into account'. Thus the attainment target about decision making runs the chance of remaining an empty shell, where this attainment target could be crucial in making the required knowledge acquisition relevant for students in coping with decision-making situations in (their) everyday life.

Motive

The importance of decision making, be it in environmental education or STS-flavoured physical science education, and the chance of a minimal operationalisation of the attainment target dealing with decision making provided a first broad motive for the research to be described in this study – a motive not in the least inspired by my personal involvement in both the PLON project and the NME-VO project. The idea was to prepare and investigate the teaching and learning about a specific science/technology-related social issue and related decision making in classroom practice, guided by the following question: which science knowledge is necessary as a conceptual input into which decision-making procedure? This question reflects a combination of the two earlier identified issues: the tuning of conceptual science knowledge to everyday life decision-making situations in which it has to be used productively, and the operationalisation of the attainment target about decision making.

The earlier mentioned issue of how to have students acquire this science knowledge will be dealt with in the next section.

1.3 The teaching/learning process: top-down or bottom-up

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 as mentioned in the previous section. 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 further extend these in a specific direction.

Educational constructivism

Taking the students' pre-knowledge into account reflects the adoption of the perspective of *educational constructivism* (Ogborn, 1997), in which learning seems to be viewed as a process in which the learner actively constructs new knowledge by interpreting new experiences and information on the basis of what he or she already knows (e.g., Driver *et al*., 1994; Matthews, 1994; Duit & Treagust, 1998). As it is not really clear what 'actively constructs' might mean, it might be better to reformulate this as follows: a process in which the learner is actively involved in the integration of new experiences and information into what he or she already knows (Vollebregt, 1998). Although this idea may sound rather simple, it is not at all easy to incorporate it in the design of an effective teaching/learning process. Different ideas about a constructivist teaching/learning process in which the students' pre-knowledge is taken into account have been put forward, such as the status-changing model of conceptual change (Posner *et al*., 1982) and conflict strategies (Nussbaum & Novick, 1982; Driver & Oldham, 1986). To a greater or lesser extent, these strategies consider the students' pre-knowledge as being wrong ideas that have to be changed into or replaced by the, from a science point of view, right ideas.

A first problematic aspect of these constructivist teaching/learning strategies is that students are expected to start their learning process by making explicit and using their pre-knowledge, and at roughly the same time are expected to devaluate or reject these ideas. This may have a negative impact on the students' motivation to learn and on the cognitive learning effects of the teaching/learning process. Secondly, and more important, these strategies to a greater or lesser extent assume that the students' pre-knowledge is largely wrong. This assumption might not be valid, and would be at least unfair to the students as their ideas are being measured against correct science. It is exactly this correct science that students are expected to acquire in their prospective learning process. If the interpretation of the students' ideas is

being based on what they are *not* saying (that is: correct science), the value of what they *are* saying gets lost. And what they are saying may make perfect sense from an everyday life point of view. It might be somewhat counterproductive to qualify these correct ideas as being wrong. This reflects the underestimated 'problem of interpretation' in science education (Klaassen & Lijnse, 1996): what do students really mean when they say what they say, how to interpret their ideas as being coherent and sensible? Once this problem has been solved, the students' properly interpreted pre-knowledge can be used productively as a starting point for a teaching/learning process aimed at extending their knowledge, for example by making it more precise and applicable to an expanding range of situations. It must be noted, however, that this seemingly straightforward relationship between pre-knowledge and extending knowledge is not always as straightforward as suggested above. Concerning the domain of particle models, for example, it can be argued that students have no pre-knowledge at all. In that domain, therefore, one will have to start from the students' pre-knowledge in quite another domain (Vollebregt, 1998).

A problem-posing approach

The intention of taking the students' pre-knowledge seriously as indicated above seems to point at the desirability of some kind of a *bottom-up* teaching/learning process (Lijnse, 1995): a sequence of teaching/learning activities designed on the basis of a profound knowledge of the students' relevant pre-knowledge and of its development, building on a proper interpretation of their knowledge as being coherent and sensible (instead of as 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) – *No dark sarcasm in the classroom …*

According to this view the teaching/learning process should reflect a careful balance between 'guidance from above' and 'freedom from below' (ten Voorde, 1977; Freudenthal, 1991; Lijnse, 1995). This guidance from above is provided by the teacher and the teaching materials. It is needed to have students arrive at the very ideas one wants to teach. Such a guided teaching/learning process might be structured (from above) by a sequence of interrelated teaching/learning activities, starting from a proper interpretation of the students' relevant pre-knowledge and carefully guiding them in making transitions from one teaching/learning activity to the next. 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 further drive the teaching/learning process. This reflects the element of 'freedom from below', as the teaching/learning process is then also guided (from below) by the students' own motives, knowledge and questions, so that they themselves frame the questions that drive their learning process (Klaassen, 1995) – *Teachers leave the kids alone …*

These ideas about a problem-posing teaching/learning process will be dealt with more extensively in chapter 3.

Developmental research

Finding a reasonable balance between 'guidance from above' and 'freedom from below' in the teaching/learning process is not an easy task. Too much guidance from above might easily result in another top-down teaching/learning process. Too much freedom from below might result in an aimless teaching/learning process, not having the students arrive at the very ideas one wants to teach. In designing the teaching/learning process one has to start with reasonable assumptions about the students' existing and (as a result of the intended teaching/learning process) developing motives and knowledge. These assumptions have to be checked empirically, and the findings have to be used for creating an optimal balance between the elements of guidance and freedom in the (revised) teaching/learning process. Designing the teaching/learning process is therefore necessarily an empirical process of closely interconnected research and development. This process has been called *developmental research* (Gravemeijer, 1994; Lijnse, 1995): a cyclical process of reflection on contents and teaching/learning process, small-scale curriculum development and teacher preparation, and classroom research of the interaction of teaching and learning processes. This eventually leads to an empirically based description and justification of the teaching/learning process for the topic under consideration. Developmental research, in other words, is an adequate means to arrive at a domain-specific educational theory, which we also call a *didactical structure* for that domain. Such a didactical structure encompasses the didactical starting-points and a related global outline of the teaching/learning process. It should be noted that the word 'didactical' is a translation of a word that is well known in many European languages, which should not be confused with the negative meaning of the English 'didactic teaching' – as should be apparent from the above outline of the intended teaching/learning process.

Motive

These ideas about designing a bottom-up teaching/learning process provided a second broad motive for the research to be described in this study. The idea was to design a didactical structure for the teaching/learning of a specific science/technology-related social issue and related decision making, guided by the following question: what does a problem-posing teaching/learning process for this topic look like? After the first question about which science knowledge is necessary as a conceptual input into which decision-making procedure as stated in the previous section, this

second question reflects the issue of how to have students acquire this science knowledge and use it for the purpose it has been acquired for. That is: their decision making about the specific science/technology-related social issue.

1.4 Research

In the preceding two sections the questions about the appropriate science knowledge for decision making on science/technology-related social issues, the decision-making procedure, and the design of an effective teaching/learning process have been stated in rather general terms. However, designing a didactical structure is a topic-specific activity. The topic chosen for the research to be described in this study is *decision making* about the *waste issue*, one of the environmental issues featuring in the attainment targets for junior secondary education. The attainment targets in the skills and content domains related to this topic as stated in the programme at the time the research started have been reproduced in figure 1.1. It must be noted, however, that the programme does not explicitly connect specific attainment targets in the skills domain to those in the content domains. Therefore, the suggested connection between the attainment targets reproduced in figure 1.1 is a matter of interpretation.

Skills domain
With respect to the attainment targets in the content domains, the students are able
- to present an argued point of view in a decision-making situation.

Content domain: substances and materials in the home
The students are able
- to state how in using substances, materials and products at home the environment can be taken into account, and to suggest ways to counter dissipation and pollution
- to state the environmental effects of waste processing.

Figure 1.1 – Attainment targets related to decision making about the waste issue in the Dutch physical science curriculum for junior secondary education.

The reasons for choosing this topic are threefold. First of all, at the time the research started the waste issue was, comparable to the context of (environmental) decision making, a relatively new element in the physical science programme. Secondly, this waste issue seemed rather fit to be put somewhere in the beginning of the curriculum. Thus the waste issue would be a suitable topic to start tackling the attainment target about decision making. The results of the study would then have relevance for teaching practice in two areas, as they would offer teachers an example of the teaching/learning about a relatively 'new' element of the content domains (waste) in the context of an equally 'new' element of the skills domain (decision making). Moreover, it was expected that without too much difficulty this example could be extended to the teaching/learning about other environmental issues included in the

programme. Finally, it was expected that this example could give an idea on how to proceed with a further elaboration of the attainment target about decision making in the course of the two-year physical science programme for junior secondary education.

The third reason for choosing this topic of decision making about the waste issue is of a different kind. The chosen topic reflects an interaction between the acquisition and application of knowledge. Or, in other words: an interaction between the students' development in the domains of knowledge and skills. The growing emphasis on skills development in (secondary) education in the areas of investigating, designing, problem solving and decision making triggers the question of the existence and applicability of 'general strategies' in these areas: are these general strategies – if existent – independent of domain-specific knowledge, or are they also domain specific (e.g., Perkins & Salomon, 1989; Hennessy *et al.*, 1993; Boersma, 1994)? It was expected that the results of the study – next to ideas about how to proceed with a further elaboration of the attainment target about decision making – also might allow some generalisations to be made about the interaction between knowledge and skills development in these other areas.

General research question

With this specification of the topic, the *general research question* for this study can be formulated as follows:

- *What constitutes an adequate didactical structure through which students in junior secondary education learn to use their acquired knowledge about the waste issue in a satisfactory decision-making procedure?*

As already stated earlier, the term 'didactical structure' in this research question refers to a didactical description and justification of a *problem-posing* teaching/learning process. This didactical structure for the topic under consideration could be considered to be valuable on its own. In addition, it might be considered to be *exemplary* in two different ways. First of all, maybe the waste issue could be exchanged for any other environmental issue or, even more general, for any science/technology-related social issue. Secondly, maybe decision making could be exchanged for other skills, such as investigating, designing and problem solving. Of course, in both cases quite extensive domain-specific adaptations will be necessary at the level of student activities. But in general terms this topic-specific didactical structure might then be considered as an example for the teaching/learning about other topics, characterised by a combination of attainment targets from a content domain and the skills domain.

Thesis outline

This chapter has given two broad *motives* and a subsequent *general research question* for the study to be reported in this thesis. However, the questions about the appropriate science knowledge for decision making on science/technology-related social issues, the decision-making procedure and the design of an effective teaching/learning process have been stated in rather general terms. In chapter 2 these ques-

tions will be explored at a more topic-specific level by looking at 'standard' approaches to decision making about environmental issues in NME-VO project's materials and in textbooks for junior secondary education. This will result in a number of *specific research questions*.

Designing a didactical structure through the method of developmental research should start with a *reflection* concerning the educational aims, the assumptions about the students' existing and lacking issue knowledge and decision-making skill, and the character of the teaching/learning process. The ideas resulting from such a reflection are presented in chapter 3, culminating in a first outline of a didactical structure for the teaching/learning of decision making about the waste issue. Chapter 3 also addresses the use of a *scenario* as an instrument for designing the sequence of student tasks, for preparing the teacher on the classroom trial and for evaluating this trial.

The developmental research has gone through two complete cycles of reflection, curriculum development and classroom trial. The resulting second – and, for the time being, final – version of the teaching/learning unit (as an operationalisation of the didactical structure) for the topic of decision making about the waste issue is described to some detail in chapter 4. The 'history' of this curriculum development effort is presented in chapter 5, which focuses on the classroom trial of the unit's first version, in order to reveal the validity of the assumptions about the students' issue knowledge and decision-making skill but also the structural errors in the design of the teaching/learning process and the inadequate preparation of the trial teacher. Subsequently, the ensuing modifications of the unit's first version and the teacher's preparation on the classroom trial of the unit's modified, second version are dealt with. The results of the classroom trial of the unit's second version are presented in chapter 6. These trial results are used to tentatively answer the question whether or not the teaching/learning unit (and the underlying didactical structure) now is 'good enough' for practical purposes. That is: effective classroom teaching. Although the answer to this question is (going to be) more or less affirmative, at some instances the scenario and/or classroom practice cannot yet be considered as satisfactory. These yet unsatisfactory trial results will be used to indicate in which way both should and could be further improved upon. As these ideas are based on classroom events that were not used to their full potential, this chapter identifies a (potential) gain of the research in terms of classroom practice.

The thesis is concluded in chapter 7 with first reflecting on the results of this study in the light of the two broad motives for undertaking it as expressed earlier in this introductory chapter, and summarising the answers to the specific research questions. This is followed by an attempt at describing the topic-specific didactical structure resulting from the study in more general terms as a *problem-posing, level-structured* didactical structure in which students are expected to make motives-driven transitions between distinct levels of knowledge and skill, facilitated by a sequence of teaching phases each having a distinct didactical function. The potential of such a generalised didactical structure for the teaching/learning in the domains of knowledge and skills will be briefly explored by applying it to developing a

decision-making strand in the physical science curriculum at the junior secondary level and to the teaching/learning of complex intellectual skills other than decision making – which might be a (potential) gain of the research in terms of ‘didactical theory’.

2 The problem: intuitively messing about – garbage in, garbage out ...

2.1 Introduction

The two broad motives for the research and the related general research question given in chapter 1 could both be considered as the result of my earlier curriculum development work in the PLON and NME-VO projects and of my research in the final phase of the NME-VO project during the years 1989-1993. In this phase of what in retrospect might be called *exploratory research and development* the very first *intuitively designed* versions of a teaching/learning unit about decision making on the waste issue were written and tested. The classroom trials of this garbage unit were rather unsatisfactory with respect to learning outcomes. The purpose of this chapter is to identify the reasons for these unsatisfactory results, in order to arrive at a specification of the general research question given in chapter 1. This chapter will therefore outline the character of the first versions of the garbage unit, the results of its classroom trials and the emerging questions that have to be further addressed through developmental research. At appropriate points this description will be supplemented by some results of a survey of recently published science textbooks, reinforcing the emerging questions for further investigation.

After first giving a characterisation of intuitively designed teaching/learning materials in section 2.2, the phase of exploratory research and development in the NME-VO project concerning the topic of decision making on the waste issue is described in section 2.3. This description is intertwined with some critical reflections: what has been done with which results, and what are the reasons for these results being unsatisfactory. Finally, the resulting problem definition in terms of a specification of the general research question given in chapter 1 is presented in section 2.4.

2.2 Intuitive design

The development of teaching/learning units in the NME-VO project could be characterised as a process of *intuitively messing about*. This means that the units were designed mainly on the basis of *intuitions* about the acceptable contents, format and teaching/learning process. These intuitions did stem from a substantial experience in teaching and curriculum development, from many years of using and writing teaching/learning units for secondary school science. They could therefore be considered to represent a valuable *practice-based theory* of the teachers and curriculum developers involved (Verloop, 1992; Alblas *et al.*, 1993) – a theory

which, in the case of curriculum developers and textbook authors, might be made explicit to some extent in the teachers' guide that comes with the student materials.

Intuitively designed teaching/learning units represent an, according to the traditional content standards of the school subject, logical story written by the author(s), starting from an assumed level of the students' pre-knowledge and skills based on an estimation of the contents of preceding education. Furthermore, usually this story is regularly interrupted by questions, assignments and practicals of a reproductive and/or productive nature, mostly with the intention of applying what has been told in the story. No extensive effort is made to make clear to the students where the story as a whole (including the questions, assignments and practicals) is leading up to. The usefulness of the contents of the story, and thus of what has to be learned, is mostly left implicit. Apparently, the students are expected to follow the trail of thought in the story as set out by the author(s), all too often without being stimulated to actively digest that what has to be learned.

Of course, there are modifications to be made to this characterisation (or caricature) of intuitively designed teaching/learning units. Sometimes questions are inserted with the intention of giving the students an orientation on what will be told in the next part of the story. But then the orienting nature of these questions often remains implicit. Sometimes some kind of 'attainment targets' are formulated by the author(s) at the beginning of the story in an attempt to give students an idea of what they are up against, or what they will know and be able to do in the end. But then it is questionable whether the students will be able to understand those targets at that (early) moment and to connect those targets to what the story is telling. Sometimes some 'history of science' is included in the story, to show the difficulty and non-linear progress of scientific discoveries and explanations through (examples of) scientific controversy. And sometimes some kind of connection with the world of everyday life is introduced by the author(s) at the beginning of and/or throughout the story in an attempt to show students the relevance of the story for understanding natural or technological phenomena in daily life or for coping with science/technology-related social issues (Eijkelhof & Kortland, 1988) – a *science in context* or STS approach. In connection to this approach the questions and assignments more often concern practical situations with a personal or societal flavour. But in all these cases the story is still the story of the author(s) which students are expected to more or less passively follow until the end.

2.3 Exploratory research and development

The characteristics of intuitively designed teaching/learning materials are clearly recognisable in the NME-VO project's unit about decision making on the waste issue for grade 8 or 9 middle ability students: *Garbage – dumping, burning or reusing/recycling*. Not only the process of designing this unit could be considered as intuitively messing about, but also the connected research: certainly the first trials of

the unit were a matter of going into the classroom and 'just see what happens' without having a clear idea of 'what to look at'. Notwithstanding these weaknesses, the results of this phase of exploratory research and development have been useful for arriving at a problem definition for further developmental research. These results have been reported quite extensively elsewhere (Kortland, 1992a; 1996a; 1997), and will only be summarised below. This summary will concern an outline of the garbage unit's *design*, the process of *research and development*, the interpretation of the students' *pre-knowledge* and *decision-making skill*, the unit's *modified design*, the *classroom observations* during its trial and its *learning effects*. For the purpose of this chapter this summary is intertwined with a supplementary critical reflection on what has been done and found in this phase of exploratory research and development.

Design

The topic of the garbage unit was limited to the fraction of packaging waste in household garbage. The first, large part of the unit was concerned with first making an inventory of the students' pre-knowledge about the waste issue, followed by providing information about the environmental problems (depletion of renewable and non-renewable raw materials, and pollution of air, water and soil through dumping and burning waste) and the options for a more sustainable use of the environment with respect to matter (e.g., use of renewable raw materials, prevention, reuse of packages and recycling of packaging materials). This was done by means of a text intertwined with reflective questions (e.g., about whether and why students think depletion and pollution are serious problems, and which options are effective solutions for which problems). This knowledge part of the unit was considered necessary before going into decision making about household packaging waste in the second part of the unit.

The decision-making exercises near the end of the unit were structured, reflecting a *criteria* format for decision making (Kortland & Veldman, 1992): comparing two or more alternatives on a number of criteria. The students were asked to answer a number of given questions and any other questions they themselves might find important about two alternative packages in a matrix format. The given questions were based on the preceding knowledge part of the unit, and concerned the package's necessity, reusability, recyclability and harmfulness when dumped or burned. These questions could be seen as *environmental criteria* for comparing packaging alternatives. In answering these questions, students were referred to a separate database with information about the different packages and packaging materials. The students were finally asked to present the results of their decision making on different situations to the class: their preferred alternative, and – more important – their argumentation leading up to this preference.

Reflection – With respect to the issue of the character of the *teaching/learning process* identified in chapter 1, the design of this unit was another example of a strategy of *top-down* transmission – despite its start with a teaching/learning activity

of making an inventory of the students' pre-knowledge. This pre-knowledge was not used productively in one way or another: the knowledge part of the unit just started at the beginning of the 'waste story', simply ignoring the previous teaching/learning activity. This could be seen as a rather weak operationalisation of the educational constructivist idea that "the teacher must have a good idea of what concepts the pupils might already have and then engage pupils in activities that would help them construct the desired understanding" (Duit *et al*., 1992). The problem of 'how to use the students' pre-knowledge' was left completely for the teacher to solve.

Survey – Decision making about science/technology-related social issues is part of the new Dutch national curriculum for junior secondary physical science education, as indicated in chapter 1. This topic is therefore included in recently published textbooks for this type of education. As most textbooks are still written intuitively, the same problem as identified in the above reflection concerning the NME-VO project's garbage unit might be expected. A scan of the textbooks that pay some substantial attention to the topic did indeed show the predominant strategy suited for top-down transmission: a story about the science/technology-related social issue at hand, intertwined with or followed by questions and exercises. A small portion of these exercises is dealing with decision making.

Research and development

While developing the unit's first version, a structured interview with a limited number of four male and four female grade 8 middle-ability students (ages 13-14) was used for getting some insight into their pre-knowledge of the waste issue and decision-making skill. This limited number of students was thought to be enough for preparing the first version of the unit, as the classroom trials would provide an opportunity to get a more detailed picture. The two trial schools and (experienced) trial teachers were asked to participate on the basis of their interest in educational innovation. Within the prospective trial classes, the students to be interviewed were identified by their teacher on criteria such as average intellectual and communicative ability.

The unit's first version was tested by the two teachers, in two grade 8 middle-ability classes each (approximately 90 students in total), during the school year 1990-91. The classroom observations gave rise to a somewhat modified design of the unit, which was tested in the 1991-92 school year by one of the trial teachers in two small, middle-ability classes (27 students in total). A pre- and post-test questionnaire was used to assess the students' progress on issue knowledge and decision-making skill.

Pre-knowledge

The structured interviews and first classroom trials were – quite in line with the fashion at that time – aimed at identifying students' *misconceptions*: missing, vaguely distinguished and/or wrongly interpreted concepts and relationships in the students' issue knowledge (Kortland, 1991; 1992b; 1997). The students' pre-knowl-

edge was found to lack ideas about the relationship between dumping or burning waste and depletion of raw materials, and about the practical limitations of reuse and recycling. It was also concluded that they had difficulties in making a distinction between renewable and non-renewable raw materials (with recyclability as a criterion for renewability), between recyclable and non-recyclable packaging materials (with separate waste collection or biodegradability as a criterion for recyclability), and between reusability of a package and recyclability of a packaging material (with recyclability as a criterion for reusability).

In the knowledge part of the unit these supposed misconceptions were addressed as clearly as possible, under the assumption that students with that help would arrive at a more complete and correct body of issue knowledge. However, some of these misconceptions still emerged in the students' reports about their decision making near the end of the unit, without being challenged by the student audience.

Reflection – These early signals of persistent misconceptions should have raised at least three questions, relating to the issues of the character of the *science knowledge* necessary for decision making and of the character of the *teaching/learning process* identified in chapter 1: is the science knowledge transmitted by the unit adequate for the decision-making exercises, is the design of the teaching/learning process adequate for acquiring this knowledge, and is the students' pre-knowledge interpreted correctly? Apart from the fact that these questions were not raised at that time, in retrospect they have to be answered in the negative. The unit concentrated on transmitting general issue knowledge, and it was left to the students' own initiative to turn to the database for more specific information about packages and packaging materials relevant for the decision-making exercises. So, the balance between general and more specific issue knowledge seems to be wrong. In such a case the inadequacy of the already mentioned top-down teaching/learning process is not so relevant any more. Finally, the students' pre-knowledge has been interpreted negatively in terms of misconceptions, and as such it has not provided a fruitful starting point for the teaching/learning process.

Survey – A number of recently published textbooks for junior secondary physical science education have been analysed with respect to the information about the waste issue provided by the textbook and the issue knowledge required for tackling the related decision-making exercises. The general conclusion must be that these two bodies of knowledge do not always match. An example is a story about hazardous household waste, followed by a decision-making exercise in which students are asked to choose between a pocket calculator operating on batteries or solar cells (de Jonge *et al.*, 1993, pp. 131-133). The textbook information about batteries seems to be adequate for decision-making purposes, although one might expect this information to be part of the students' pre-knowledge to which the textbook does not add very much. However, no information about the environmental impact of solar cells is being given. Another example: a story about the environmental impact of the use of materials and countermeasures such as the use of renewable raw materials,

prevention, reuse and recycling, intertwined with and followed by decision-making exercises (Kortland, 1994, pp. 32-38). This general information seems to be adequate for tackling the included decision-making situations of a same general character, such as those about deciding between prevention and reuse/recycling or between reuse and recycling. But the exercises also include some more specific decision-making situations, such as choosing between a plastic and a paper carrier bag, and between a returnable plastic bottle and a carton. The necessary information about the waste-related properties of such packaging materials and packages provided by the textbook is not clearly presented and certainly incomplete.

These two examples illustrate that also recently published textbooks give rise to questions about the necessary body of issue knowledge for decision making and about the interpretation of the students' pre-knowledge.

Decision making skill

The structured interviews were also meant to get an initial idea of the students' issue-related decision-making skill. At the start of the interview they were presented with a decision-making situation concerning milk packages: carton or glass bottle – which one to choose, and why? Again – comparable to the focus on identifying misconceptions in the students' pre-knowledge – the interpretation of their initial argumentation was mainly aimed at identifying what was missing, vague and wrong (Kortland, 1991; 1992b; 1996a). As a result, the students' decision-making skill was assessed as being limited. Although most students did make an explicit or implicit comparison of the packaging alternatives on one (and sometimes more than one) criterion, these comparisons were considered to be incomplete or incorrect, the criteria to be vague, and the range of criteria to be narrow. Moreover, on this narrow range of criteria the outcomes of the comparisons were exclusively supportive of the decision made. As a consequence any weighting of 'conflicting' comparisons was lacking. However, further questioning in some of the interviews provided an indication that students might be more knowledgeable about the decision-making situation than reflected by their initial argumentation. In some cases the students' continued argumentation did yield additional criteria, and did show conflicting comparisons and a subsequent weighting. It appeared that the criterion attributed a higher weight in the end was the same as the criterion used by the students in their initial argumentation. So, for at least a portion of the students the range of criteria used was probably not so narrow. It might be assumed that they just did not see the 'necessity' of mentioning all these criteria except the one(s) perceived by them as being more important.

In the decision-making part of the unit this supposedly limited decision-making skill was only addressed by providing the students with a matrix format for comparing alternatives on a number of given criteria. This appeared to have a positive effect on the students' argumentation in their reports to the class: although the comparisons were still considered to be incomplete or incorrect, the criteria in general were less vague and the range of criteria less narrow. In some reports also weighting of conflicting comparisons took place.

Reflection – These signals of a still rather weak learning effect should have raised at least three questions, relating to the issues of the character of the *decision-making procedure* and the character of the *teaching/learning process* identified in chapter 1: is the decision-making procedure prescribed by the unit tuned to the students' decision-making skill, is the students' decision-making skill interpreted correctly, and what do they still have to learn about decision making? Again in retrospect, not all these questions have been addressed properly. To start on a positive note: the criteria format for decision making in the unit seems to be adequately tuned to the students' decision-making skill of comparing alternatives on criteria, and does seem to help them in structuring their decision making. However, the 'incomplete or incorrect comparisons of alternatives on a narrow range of vague criteria' should not have been interpreted in terms of a limited decision-making skill. These deficiencies point at a lack of sufficient issue knowledge. And, as mentioned earlier, the design of the teaching/learning process is not adequately addressing the students' acquisition of issue knowledge. It therefore cannot be expected that near the end of the unit the students' argumentation would have improved in this respect.

What is it then that students still have to learn about decision making? The students' initial use of a narrow range of criteria and the emergence of a broader range of criteria and associated weighting through further questioning should have been interpreted in terms of inexperience in *presenting* an argued point of view to others as completely and clearly as possible, as well as unfamiliarity with some kind of *standard* for such a presentation. This could have been one of the things to learn about decision making – but was not addressed in the unit. Secondly, the students' decision-making skill of comparing alternatives on criteria should have been qualified as quite satisfactory. Making this skill explicit in terms of a decision-making procedure would have provided the students with a general tool for tackling other – for them new and complex – decision-making situations. This was also not addressed in the unit.

Survey – The recently published textbooks for junior secondary physical science education have also been analysed with respect to the way in which the students' decision making is being structured. Depending on the textbook, the decision-making exercises reflect an *open* format, a *pros-and-cons* format or a *criteria* format, in line with the findings in an earlier review of decision making in teaching/learning materials for environmental education across the world in the NME-VO project (Kortland & Veldman, 1992). The *open* format does not offer the students much help in structuring their decision making: after presenting the decision-making situation, the question put to the students is one of 'What do you choose, and why?' In the *pros-and-cons* format the students are asked to think of as many pros and cons of each alternative as possible, and to decide about the preferred alternative by reflecting on this inventory. In the *criteria* format the students are asked to compare the alternatives on each of a set of criteria, and to decide about the preferred alternative by reflecting on these comparisons. In these cases the set of criteria is mostly given. The task of the students is to use their issue knowledge for comparing

the alternatives on each criterion, followed by weighting these comparisons in order to arrive at a decision. In some cases also the comparisons are given (for example by presenting the results of a consumer product test), thus leaving only the weighting and deciding to the students. Only occasionally the students are asked to generate alternatives and/or to develop criteria by themselves.

The pros-and-cons and criteria formats offer students some help in structuring their decision making. From the point of view of structuring the available information about alternatives, the criteria format might be of somewhat more help. A pro of one alternative quite often is a con of the other alternative and vice versa. In the pros-and-cons format these connections might be difficult to trace, while in the criteria format they are part of the comparison on one of the criteria. From the point of view of the students' input into the decision-making procedure, the pros-and-cons format is somewhat more demanding. The students have to identify the pros and cons by themselves. In the criteria format the 'pros and cons' are – in textbook practice – defined by the given criteria. However, the criteria do not necessarily have to be given.

The offered pros-and-cons and criteria formats seem to aim at structuring the students' decision making in order to arrive at 'the best decision'. A complete and clear presentation of such an argued point of view to others is not addressed. Moreover, no textbook has been found in which the offered format is made explicit in general terms to represent a decision-making procedure as a general tool for the students in their future decision making. The one (at that time known) exception to this rule was a Canadian science textbook, finishing off with a *Guide for thoughtful decision making* (Aikenhead, 1991, pp. 237-247). This guide presents and explains a sequence of steps to be taken (such as, roughly: identifying the problem, generating alternatives, identifying and weighting positive and negative consequences of each alternative) in order to arrive at a thoughtful decision. The inclusion of this guide was, by the way, recommended by the students during the trial of the textbook's first version as they were of the opinion – triggered by a friendly confrontation with the textbook author's expectations – that such a sequence of steps would enable them to improve on the quality of their decision making (Aikenhead, 1991, personal communication). More recently, an explicit criteria format was also used in a case-study on students' decision making about socio-scientific issues in science classes (Ratcliffe, 1994), with the aim of offering the students some help in structuring their decision making.

The results of this survey illustrate that also recently published textbooks give rise to questions about an adequate decision-making procedure and a related standard for the presentation of an argued point of view.

Modified design

The above questions regarding the interpretation of the students' pre-knowledge about the waste issue and decision-making skill as well as the adequacy of the teaching/learning process have been formulated in retrospect. The revision of the unit for a second round of classroom trials was guided by quite another question:

how to explicitly address the students' supposed misconceptions in the areas of issue knowledge and decision making. More or less in line with those constructivist approaches of the 1980s that deliberately employ cognitive conflict (Duit & Treagust, 1988), the answer to this question was sought in the direction of some kind of *conflict strategy*.

During the process of revision, the garbage unit's first version was 'enriched' with two additional teaching/learning activities. The first one was inserted as a starter for the unit: the bottle/carton decision-making situation about milk packaging featuring earlier in the structured interviews. The students were asked to tackle this decision-making situation in small groups, and subsequently to report their results to the class. The students' decisions and argumentation would thus serve as the input into an open whole-class discussion in which different points of view are put forward and in which arguments can be exchanged and questioned (Bridges, 1979). A discussion not aiming at reaching consensus about 'the best decision', but with the aim of having the students 'discover' their 'limited decision-making skill' with respect to the range of criteria used by them for comparing the packaging alternatives. On the basis of what happened during the interviews, it was expected that each group of students would present a decision supported by a comparison of the alternatives on one criterion only, and that different groups of students would come up with different criteria. This 'conflict' between the different groups of students was supposed to make them aware of the necessity to compare the alternatives on a broad range of criteria.

The second additional teaching/learning activity was inserted near the end of the unit's knowledge part: a number of everyday life decision-making situations concerning packaging, implicitly addressing the students' supposed misconceptions about the waste issue as identified through the interviews and first classroom trials. The decision-making situations were designed in such a way that a student's decision would be dependent on him or her 'having a misconception'. Again, the students were supposed to tackle these decision-making situations in small groups and to report their results to the class. It was expected that each one of the decision-making situations would trigger a 'conflict' between the different groups of students about 'the best decision'. The task of the teacher would be to identify the misconception underlying such a 'conflict' by further careful questioning of the students involved.

Classroom observations

During both additional teaching/learning activities the intended 'conflicts' did indeed arise as expected. However, the way in which these conflicts were dealt with in the whole-class discussion proved to be unsatisfactory. During the first additional activity the 'limited range of criteria' used by each group of students 'disappeared' as the contributions of all groups were summarised in one scheme. This offered the teacher the possibility to point at the 'requirements' of comparing alternatives on a broad range of criteria and associated weighting in order to arrive at an argued point of view. However, these requirements were introduced far too implicitly, and did not

come forward as a result of a reflection by the students on their own 'limited' contribution to the broad range of criteria resulting from their collective effort. So, in comparison with the unit's first version this additional teaching/learning activity could not be expected to make much difference with respect to improving the students' presentation of an argued point of view.

During the second additional activity aimed at 'identifying misconceptions' it appeared that the teacher had difficulty in giving up the familiar role of instructor: the decision-making situations were settled too quickly by suggestive questioning or instruction from the part of the teacher. As a consequence the supposed misconceptions were not identified, nor discussed to some extent, and the teaching/learning process again reflected one of top-down transmission. So, apart from the question whether there were any misconceptions to be addressed, the additional activity would therefore not have been of very much help in addressing these.

Reflection – The classroom observations during both additional teaching/learning activities clearly point at the necessity of a more extensive *procedural specification*: given the task, what are the students expected to put forward, what is the teacher expected to do with that in which way and towards which end. Such a procedural specification should be considered a part of the unit's design, and should help the teacher in preparing for the trial. In both cases the lack of such a procedural specification as part of the unit's design is apparent.

Learning effects

To start with a preliminary conclusion: even if there had been misconceptions in the areas of issue knowledge and decision making to be addressed, the way in which the chosen conflict strategy has been handled in classroom practice would not have been very helpful in addressing these. The additional teaching/learning activities therefore could not be expected to have had much influence on the unit's learning effects. These learning effects have been assessed through a pre- and post-test questionnaire.

One of the tasks in the questionnaire was to present an argued point of view in the bottle/carton decision-making situation about milk packaging. The learning effects of the unit appeared to be limited (Kortland, 1996a). There was a significant increase in making an implicit or explicit comparison of alternatives on a criterion. The number of criteria used remained stable: only a small portion of the students (roughly one quarter) used more than one criterion, and in these cases only occasionally the comparisons of the alternatives on these criteria would necessitate a weighting. Students kept presenting their argued point of view in their customary way, comparable to their initial argumentation in the interviews: one or two criteria, on which the alternatives – as perceived by the students – score in a way supportive of their decision. However, with respect to the criteria used there were some changes. There was a significant shift away from questionable social 'criteria', such as 'That's what we always use at home', or 'My mother tells me to take cartons'. The most often used criterion was recyclability/reusability, with an increase in

explanations for using this criterion by referring to positive environmental effects (less waste, less pollution and/or less depletion of resources) and an increase in the recognition of the problematic recyclability of the carton because of the combination of materials (paper/plastic). These results indicated an improved use of issue knowledge, although on this criterion most students did not appear to be sure about the bottle being reused or recycled.

The improved use of issue knowledge was in accordance with the learning effects (or the lack of learning effects) in this area as established through the pre- and post-test questionnaire (Kortland, 1997): a significant increase in recognition of depletion of raw materials as an environmental problem connected to household packaging waste (though only by roughly one fifth of the students), and of reuse and recycling as an option for a more sustainable use of matter. As far as the students' supposed misconceptions are concerned, there was only a significant positive learning effect regarding recyclability not being a criterion for renewability, and the difficulty of recycling laminates.

Reflection – In the preliminary conclusion these disappointing learning effects were explained by the way in which the chosen conflict strategy has been handled in classroom practice: an inadequate interaction between the students and the teacher in the process of making the supposed misconceptions explicit and reflecting on them. However, a more valid explanation might be that the students' pre-knowledge was *interpreted* in a wrong way (Klaassen & Lijnse, 1996): instead of assuming this pre-knowledge to include misconceptions, one should look for an interpretation that makes students' pre-knowledge make sense. An example would be the students' supposed lack of distinction between reuse and recycling. A different – and far more *charitable* (Klaassen, 1995) – interpretation is that the students know the difference between reuse and recycling, but just do not know which of those two is applicable to a specific package such as the milk bottle featuring in the interviews and the pre- and post-test questionnaire. An effort at teaching about the difference between reuse and recycling then is improper (as the students know the difference), and is inadequate in solving the students' problem of tackling this decision-making situation (as the teaching does not address the reusability of the bottle). Teaching about the difference between reuse and recycling will therefore not show any learning effect if assessed through a comparable decision-making situation. An explanation of the 'lack of progress' in the students' presentation of an argued point of view might have to be sought in the same direction: a misinterpretation of the students' decision-making skill.

Conclusion

The above-described phase of exploratory research and development in the late 1980s and early 1990s reflects the 'sign of the times': a search for students' *misconceptions* – in this case about the waste issue and related decision making – and for a *conflict strategy* to deal with those effectively, embedded in an until then apparently successful practice-based theory about the design of a teaching/learning unit. At that

time it probably couldn't have been done much better. However, the assessment of the unit's learning effects through the pre- and post-test questionnaire did show rather disappointing results. The effectiveness of the unit, including the two additional teaching/learning activities, was therefore considered to be quite unsatisfactory. In retrospect, the reason for this ineffectiveness has to do with the predominant idea about students 'having misconceptions'. This idea appears to have resulted in my own misconceptions about the students' pre-knowledge and decision-making skill, and my use of a conflict strategy for addressing a maybe non-existent conflict. These observations, in combination with the emerging ideas about a bottom-up teaching/learning process, have resulted in the decision to make a new start. Not a *completely* new start, however, as the reflection on the efforts during the preceding phase of exploratory research and development have clearly indicated the questions to address – questions relating to an effective teaching/learning process, a proper interpretation of the students' pre-knowledge and decision-making skill, a match between the offered and the required issue knowledge for decision making, a clear idea of what students are expected to learn about decision making, and an adequate teacher preparation on the unit's trials.

2.4 Research questions

The attainment targets for physical science in Dutch junior secondary education indicate that education should aim at students being able to present an argued point of view, based on an understanding of, among others, the waste issue. During the phase of exploratory research and development described in this chapter, this aim – in retrospect – has not been reached to a satisfactory degree. The reasons for this have been identified to some extent. This problem definition gives rise to a specification of the general research question stated in chapter 1 (section 1.4). Answers to the following five specific research questions have to be found in a process of developmental research. The result should – in the wording of the general research question – be 'an adequate *didactical structure* through which students in junior secondary education learn to use their acquired knowledge about the waste issue in a satisfactory decision-making procedure'.

Issue knowledge
A prerequisite for students' decision making is an adequate body of issue knowledge as a conceptual input into the decision-making procedure. In the NME-VO project's garbage unit, as well as in recently published textbooks for Dutch junior secondary physical science education, there seems to be a focus on issue knowledge at a general level: depletion of resources, pollution of air, water and soil through dumping and burning waste, reuse, recycling, separate collection of hazardous (household) waste, etc. However, in a number of cases this results in a mismatch between the information provided about the issue and the information necessary for

tackling the decision-making situations presented. This concerns decision-making situations of a more specific nature, in which the decision is between two (or more) materials. The necessary information about waste-related properties such as renewability, recyclability, toxicity, etc. of materials might be lacking. This leads to a first specific research question:

- *What constitutes an adequate body of issue knowledge as conceptual input into the students' decision making?*

Decision making procedure

The NME-VO project's garbage unit, the recently published textbooks for Dutch junior secondary physical science education and other teaching/learning materials show different formats for structuring the students' decision making on science/ technology-related social issues: the open format, the pros-and-cons format and the criteria format. These formats differ in the extent to which they support the students in structuring their decision making, and might therefore also have some impact on the way in which the students present their argued point of view to others. But as a rule – with, of course, some exceptions – the decision-making procedure is being left implicit. As a consequence it cannot be expected that students in their decision making on other issues will 'automatically' adopt the procedure suggested by the earlier offered format. An explicit decision-making procedure might be considered as a useful tool for students in tackling decision-making situations related to other, to them new and complex issues. This leads to a second specific research question:

- *What constitutes an adequate procedure for the students' decision making, and could it be made explicit by them?*

Pre-knowledge and decision-making skill

In most teaching/learning materials the students' pre-knowledge – about the issue as well as about decision making – is not taken into account. And if it is taken into account (like in the second version of the NME-VO project's garbage unit), the students' ideas are quite often interpreted as being 'misconceptions': the ideas are wrong, vague, incomplete and incoherent from a science point of view. And as these 'misconceptions' may lead to incorrectly argued decisions by students, these 'errors' have to be 'corrected' in one way or another. In the case of the garbage unit the chosen conflict strategy for doing this did not appear to be very successful. The reason might very well be that the interpretation of the students' pre-knowledge and decision-making skill is incorrect. A teaching/learning process addressing non-existent 'misconceptions' cannot be effective. Instead of searching for 'misconceptions', one should look for an interpretation that makes students' pre-knowledge and decision-making skill make sense – to be used productively in the design of the teaching/learning process. This leads to a third specific research question, related to the first one about an adequate body of issue knowledge for decision making and to the second one about an adequate decision-making procedure:

- *What constitutes a proper interpretation of the students' pre-knowledge about the waste issue and their decision-making skill?*

Teaching/learning process
In the NME-VO project's garbage unit the teaching/learning process reflects a strategy of *top-down* transmission, including the two additional 'constructivist-flavoured' teaching/learning activities in the unit's second version – as can be concluded from the classroom observations. In general, a top-down strategy results in forced concept development and disappointing learning effects – so would it not be better to design a teaching/learning process reflecting a *bottom-up* strategy (Lijnse, 1995)? A teaching/learning process in which (a proper interpretation of) the students' everyday life understanding of the waste issue is being used productively to generate a number of questions for further investigation of the issue. A teaching/learning process, also, in which the students' pre-knowledge and decision-making skill is being used productively in learning to present an argued point of view in decision-making situations. A teaching/learning process, finally, in which the context of decision making is clear from the start, instead of being some kind of an appendix. All this might provide students with a motive for learning, an idea of their prospective learning process and a chance to extend their issue knowledge and apply it in decision making – guided by a sequence of carefully designed teaching/learning activities that make this possible. This leads to a fourth specific research question, related to each of the three preceding questions:

- *What constitutes a good enough bottom-up teaching/learning process for decision making about the waste issue?*

Teacher preparation
Designing a bottom-up teaching/learning process is one thing, empirically testing it is quite something else. The classroom trial of the designed teaching/learning process involves a teacher. In the intended bottom-up teaching/learning process the teacher's task is one of carefully guiding the students through the sequence of teaching/learning activities, interpreting properly and using productively what students put forward in the social process of classroom interaction between students and between students and teacher. This task is not at all easy, as most teachers are used to a teaching/learning strategy of top-down transmission – like the teacher in the trial of the two additional 'constructivist-flavoured' teaching/learning activities in the garbage unit's second version. This leads to a fifth and final specific research question:

- *What constitutes an adequate teacher preparation for implementing the designed bottom-up teaching/learning process in classroom practice?*

2.5 Reflection

The title of this chapter not only characterises the phase of exploratory research and development within the NME-VO project as being one of *intuitively messing about*, but also reflects the quality of its product: *garbage in ... garbage out ...*

The effectiveness of the garbage unit leaves much to be desired. So: garbage out. The reasons for this ineffectiveness are, generally spoken, an underestimation of the didactical problems and an inadequate view on teaching/learning processes. So: garbage in. These qualifications in terms of garbage are, however, a bit too strong and too negative. The critical reflection on the research and development of an ineffective garbage unit and its classroom use by a co-operative but with regard to this unit still 'inexperienced' teacher has provided a direction for the process of developmental research to be described in this study, reflected by the specific research questions. Moreover, some parts of the garbage unit – or at least the ideas underlying these parts, such as models of the waste issue's structure and of the decision-making procedure – might even be considered as a useful input into this process. So: valuable *raw materials* instead of garbage – such as most garbage in everyday life.

3 The aim: a didactical structure for decision making about the waste issue – raw materials ...

3.1 Introduction

Designing a didactical structure for the teaching/learning of decision making about the waste issue should start with a *reflection* on its educational *aims* and on the way in which these aims could be reached. This reflection should – given the specific research questions stated in chapter 2 – concern the body of issue knowledge as a conceptual input into the students' decision making, the decision-making procedure, and the character of a bottom-up teaching/learning process in which the properly interpreted students' pre-knowledge and decision-making skill is used productively to stimulate their learning. The purpose of this chapter is to present the results of such a reflection: the *raw materials* to be processed into a teaching/learning unit for decision making about the waste issue.

This chapter first describes the ideas about a structure of environmental issues (and the waste issue in particular) and about a decision-making procedure in section 3.2. From these ideas, in combination with the ideas about the students' pre-knowledge and decision-making skill, the educational aims of the teaching/learning process emerge in section 3.3. The way in which these aims could be reached is dealt with in section 3.4, presenting the ideas about a problem-posing teaching/learning process. The combination of ideas put forward in section 3.2 up till 3.4 represents a didactical structure for the teaching/learning about the topic of decision making on the waste issue. This didactical structure is still hypothetical, and has therefore to be tested in a process of developmental research. The chapter concludes in section 3.5 with a description of the research design, including the use of a scenario as a tool for designing the detailed teaching/learning process, for preparing the teacher on the trial, for focusing the classroom observations during the trial and for guiding a post-trial reflection on the question whether or not the designed teaching/learning process is 'good enough' for practical purposes.

3.2 Issue knowledge and decision-making procedure

The development of ideas about the educational aims of the teaching/learning process to be designed has started within the NME-VO project. At a general level, these ideas have been expressed in the *core curriculum* for environmental education mentioned in chapter 1. These ideas concern a common conceptual framework for the teaching/learning about a sustainable development of the relationship between man and the environment in a range of school subjects – and this framework there-

fore also applies to the waste issue. They also concern a common stepwise decision-making procedure to be used in the different school subjects.

Environmental issues

In broad outline this conceptual framework is represented by the scheme of figure 3.1: a model of the man-environment relationship, adapted from a theoretical framework for environmental science courses at tertiary level (Udo de Haes, 1984). This model represents man as an interested party in the environment. And the environment stands for the whole of ecosystems, of which also man is a part.

For man as an interested party the environment has significance for health and security (air, water, food, shelter, etc.) next to a number of utility functions (transportation, production of luxury goods and services, recreation, etc.) which make man's life more than mere survival. Moreover, other species – as individual, in populations or in ecosystems – can be recognised as a co-interested party. Also those other species are part of the environment: a right of existence for plants and animals, unconnected to any human use. For satisfying human needs, man intervenes in the environment: extraction (e.g., of raw materials and fuels), addition (e.g., of household waste and combustion products) and alteration (e.g., of landscapes). If these interventions threaten the environment's significance, an environmental problem emerges: extraction turns into *depletion*, addition into *pollution* and alteration into *affection*.

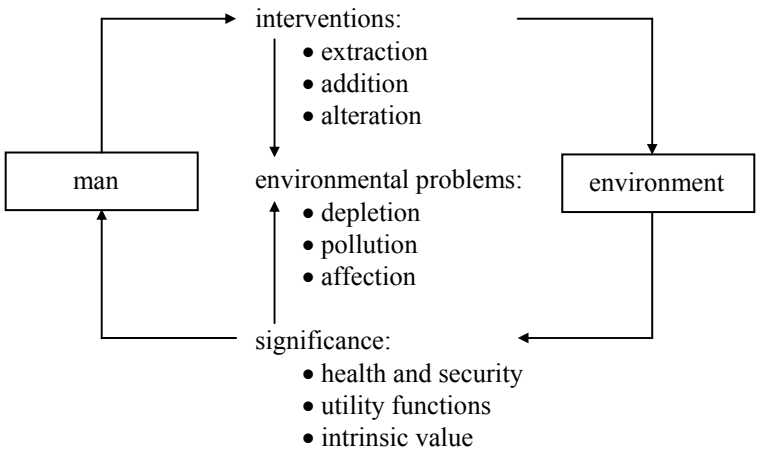


Figure 3.1 – A model of the man-environment relationship.

This conceptual framework provides a starting-point for investigating an environmental issue relative to existing problems as well as possible solutions for these problems. For each solution has its accessory new interventions, with a positive but probably also a negative impact on the environment.

Limited to the topics traditionally dealt with in physical science (or physics and chemistry) at the junior secondary level, the environmental issues would concern the

use of *matter* and *energy*. A more sustainable development of the man-environment relationship could be achieved by restricting the extraction and addition of matter (e.g., through using renewable resources, and limiting the production of waste by conserving or restoring natural, material and product cycles) and by restricting the flow of non-solar energy (e.g., through improving energy efficiency, and using renewable energy sources) (Cramer & Quakernaat, 1993).

The waste issue

In order to arrive at the educational aims of the teaching/learning process, the above outlined ideas about a sustainable development of the man-environment relationship are useful, but far too general. The conceptual framework represented by figure 3.1 has to be converted into a more specific representation of the *waste issue*. In this process it is also necessary to take a number of practical limitations into account. The necessity to avoid programme overload within the classroom time available for teaching the topic (approximately ten classroom periods of 45 minutes each) and the necessity to consider the characteristics of the target population (grade 8-9 middle ability students) did result in some initial limitations: *household garbage* only (as this relates most to the students' everyday life, and offers them an action perspective), further limited to *discarded packages* (25% of the contents of an average Dutch household garbage bag – the 50% organic waste in this bag will (have to) be 'covered' in biology lessons). And moreover: no details about different kinds of pollution, and no energy aspects of packaging and waste processing. These aspects are better dealt with at a later stage in the curriculum.

With these limitations in mind, a number of Dutch national research and policy documents on waste management (e.g., VROM, 1986; RIVM, 1989; RIVM & VROM, 1989) have been analysed in order to select and legitimate the contents to be addressed in the teaching/learning process. In combination with the above outlined general ideas expressed in the core curriculum for environmental education a model for the waste issue emerged as reproduced in figure 3.2, roughly representing the present Dutch waste management policy and practice.

This model reflects the balance between environmental problems and countermeasures (in the lower and upper part of the scheme, respectively) required by the attainment targets for physical science in Dutch junior secondary education. The model shows the environment as a source of raw materials, thus having a significance for human health and safety (packages prevent food from going bad) and utility functions (packages provide easy transport and product information). However, the use of raw materials for packages may cause depletion of non-renewable resources. On the other side of the chain the environment is being used as a dumping site for waste (discarded packages), which may cause pollution of soil, water and air. Both depletion and pollution can be regarded as environmental problems. The model also shows the possible combinations of measures for addressing both environmental problems: preventing the unnecessary use of packages, using renewable resources for packaging materials, reuse of packages and recycling of packaging

materials (with cleaning of packages and separation of different packaging materials as necessary conditions).

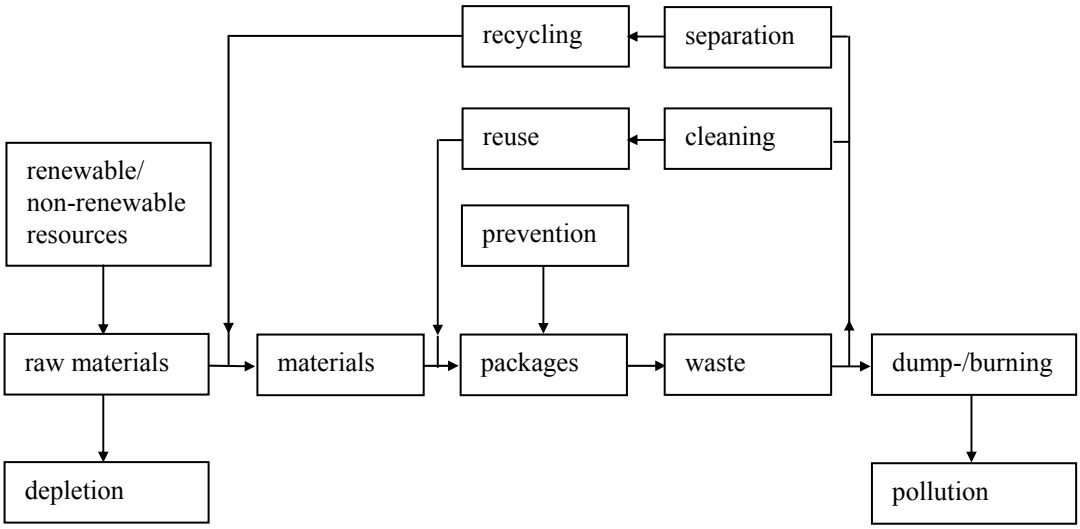


Figure 3.2 – A model of the waste issue, limited to household packaging waste.

Making this structure of the waste issue explicit, although not necessarily in the schematic form of figure 3.2, is regarded as one of the aims of the teaching/learning process: as an aim in itself (as required by the attainment targets), and as a prerequisite for students' decision making on the waste issue.

Decision making

The aim of decision making in environmental education presents some kind of controversy: is it the aim to have students arrive at a *thoughtful* decision in which 'the environment is taken into account' or to have students also act on that decision and (thus?) display an environmentally sound *behaviour*? The agreed upon recommendations of the international environmental education conferences in Belgrade (1975) and Tbilisi (1977) clearly point at the aim of a student behaviour directed at conservation and improvement of environmental quality (Hungerford *et al*., 1980; Lucas, 1980). Research into the effects of environmental education therefore quite often concentrates on measuring the environmentally sound behaviour of students and/or establishing the factors promoting such behaviour (Sia *et al*., 1986; Hines *et al*., 1987; Hungerford & Volk, 1990). However, in this research the way in which students arrive at their decision to display such behaviour is not addressed. In an extensive review of environmental education research, development and implementation it was concluded that there is a clear need for reflection on the aims and for didactical research on related teaching/learning processes in order to provide support for further development and implementation (Eberg *et al*., 1991).

From an educational point of view, the aim of decision making in terms of concrete (environmentally sound) behaviour is not considered appropriate for different reasons: danger of indoctrination, impossible to reach and to evaluate, and tied down to time (Boersma, 1986; Meijer, 1992). About *decision making* the core curriculum for environmental education mentioned in chapter 1 therefore expresses the following general ideas: environmental education should contribute to the students' ability to establish whether a decision is needed, to apply knowledge of a sustainable development of the man-environment relationship to a specific situation, to come to decisions on the basis of that knowledge, of one's own value judgements and of insight into the practicability of solutions, and to carry out a decision. This implies that environmental education should aim at extending the students' behavioural repertoire (things a student *can* do, if he or she wants to) and knowledge on which decisions about specific behaviour can be based (Boersma, 1986). The issue of the aim of environmental education and its relationship with decision making is also addressed in more recent studies (Alblas *et al*., 1993; Alblas, 1999). In those studies, from the perspective of teaching/learning processes and from a pedagogical perspective, respectively, the conclusion is drawn that the aim of environmental education should be a 'commitment to nature' (in a broad sense) and a willingness and ability to 'make informed decisions' – which *could*, but not *should,* result in environmentally sound behaviour. Therefore, also in these studies the individual responsibility of the student in weighting the interests of nature, personal interests and society's interests in his or her decision making is being stressed.

With respect to decision making, the core curriculum for environmental education mentioned in chapter 1 also suggests using a decision-making heuristic. This last idea was not yet very articulate, and could only in retrospect be connected to a preceding development of some of the NME-VO project's teaching/learning materials. However, this idea seems to point at not so much a common conceptual framework for the teaching/learning about environmental issues (as was the project's task), but more at a common stepwise decision-making procedure to be used in the different school subjects.

A decision-making procedure

Decision making has to do with issues, solution/s, values, acting, etc. A sentence in which this all seems to come together might be something like this: decision making is "the making of reasoned choices from among alternative courses of action (concerning a personal or public issue), which require judgments in terms of one's values" (Cassidy & Kurfman, 1977). This 'definition' of decision making reflects a *process*, contrary to the above-mentioned emphasis on the *product* of decision making in terms of 'environmentally sound behaviour'. Reflections on the way in which this process ideally should proceed have led to the formulation of a *normative model* for decision making (Brim *et al*., 1962). Of course, over the years many different models have been proposed and refined, but in general the common core of these models can be retraced to the "statistical decision theory for evaluating available lines of action in terms of their consequences" formulated by Bayes (1763).

This theory could be described as "a particular framework for deliberation, in which the agent's notions of the probabilities of the relevant circumstances and the desirabilities of the possible consequences are represented by numbers that collectively determine an estimate of desirability for each of the acts under consideration" and in which "the numerical probabilities and desirabilities are meant to be subjective in the sense that they reflect the agent's actual beliefs and preferences, irrespective of factual or moral justification" – which turns decision making into choosing "an act of maximum estimated desirability" (Jeffrey, 1983, p. 1). At a *qualitative* level these normative models for decision making all look like a stepwise procedure of identifying the problem, developing criteria, generating alternatives, evaluating alternatives, and finally choosing and implementing the best solution (e.g., Carroll & Johnson, 1990; Gouran & Hirokawa, 1996) – as roughly shown in figure 3.3.

In this normative model the criteria for evaluating alternatives (or: the desired characteristics of a solution) are formulated at a very early stage, in direct connection with the problem identification. At a later stage the generated alternatives are evaluated on these criteria, resulting in a decision about what seems to be the best (or least bad) solution. And finally these criteria are used in monitoring the effect of taking action: does the chosen solution indeed have the desired effects in practice?

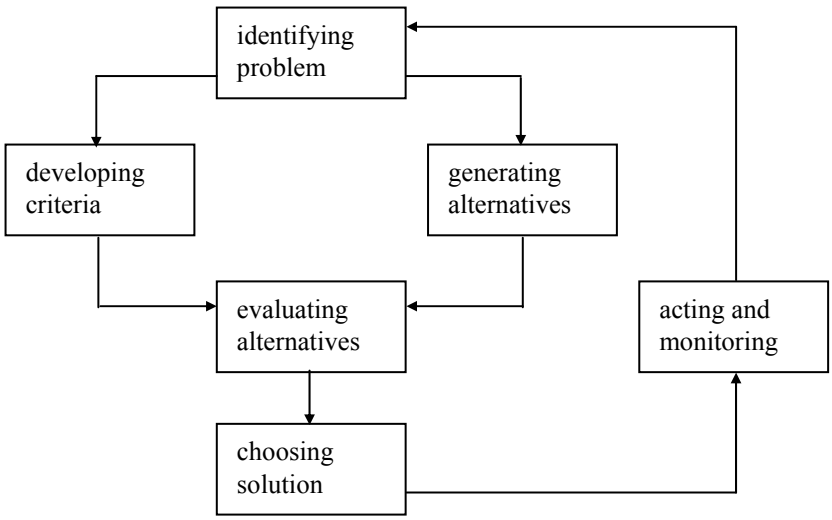


Figure 3.3 – A model of a decision-making procedure.

In everyday life, decision making does not proceed along the lines set out by this normative model. After the 'establishment' of this model in the 1960s, empirical research into decision making by professionals has identified the following 'deviations' – which, as a result of their recognisability in everyday life decision making, will not have vanished in the meantime.

- The different steps in the procedure are not separated from each other. During the step of generating alternatives, the generated alternatives are already being evaluated

(Witte, 1972). However, this might easily lead to a premature favourable predisposition towards one of the alternatives. Consequences of this predisposition might be that disadvantages of the favoured alternative and advantages of the (untimely) rejected alternative(s) are not being considered, and that the gathering and processing of information tends to be incomplete and biased (Janis & Mann, 1977).

- Criteria for evaluating alternatives are not formulated beforehand. Developing criteria interacts with evaluating alternatives: the alternatives are being compared and weighted against each other on the basis of their perceived consequences (Lindblom, 1959; Jarboe, 1996). Or, if criteria are developed in one way or another, they serve as a minimal set of requirements for an alternative being 'good enough'. In using such a *satisfycing* strategy the alternatives are examined sequentially, with no attempt to work out a comparative balance of pros and cons (Simon, 1976) and – in a strategy of elimination by aspects representing a more complex form of satisfycing – without making a distinction between minor and major criteria (Tversky, 1972).

Apparently, professional decision-makers have problems with formulating criteria beforehand, with making a distinction between the different steps and with avoiding premature decisions – or maybe their growing experience has led to automation and abridgement. However, the fact that decision making in reality differs from what the normative model 'prescribes' does not imply that the model is useless. The model could provide a framework for thinking about (solutions to) a new and complex issue, could act as a kind of checklist in order to avoid overlooking important aspects, and could structure the process over time.

Decision making in education

These advantages of the normative model might explain its seemingly predominant use in education – that is, in those few cases in which decision making is explicitly addressed in an educational setting. As a solution to the problem of how to objectively assess how well a decision has worked out, Janis & Mann (1977) propose to use "the *quality of the procedures* used by the decision maker in selecting a course of action" as a quality indicator. The major criteria used by them to determine whether decision-making procedures are of high quality roughly represent the different steps of the normative model outlined above. In an overview of educational decision-making programmes, Baron & Brown (1991a) – referring to the ideas of Janis & Mann – indicate that "most of the approaches [...] try to teach, at least implicitly, normative models of decision making" and that "several programs [...] emphasize the analysis of decisions into multi-attribute tables, in which each of several options is evaluated on each of several attributes or dimensions" requiring "(explicit or implicit) assignment of weights to various attributes." However, they also state that "most of the approaches [...] have been subjected to some degree of evaluation, but almost none have got very far toward testing for, much less demonstrating, beneficial impact on the quality of real-world decision making." In a critical review of these programmes (Beyth-Marom *et al*., 1991) a number of questions are raised with respect to their quality in terms of their goals (as some

programmes teach students how to behave as opposed to how to think), the brevity of most programmes, and the varying degree of attention paid to the full range of decision-making steps, the interaction between domain-specific knowledge and the general decision-making procedure, and the transfer to decision making under different conditions (e.g., time pressure) in real life.

A final argument for the use of a normative model when dealing with decision making in an educational setting is given by Baron & Brown (1991b) when referring to the importance of building on "what students already know about decision making." As "rudiments of decision-analytic thinking are already present in most people (Klayman, 1985) [...] it seems reasonable to try to build on the thinking of students that already corresponds to decision analysis." This observation is supported by the finding "that many, if not most, early adolescents have a basic meta-cognitive awareness of what constitutes decision making activity" (Ormond *et al*., 1991).

So, although a normative model for a number of reasons seems suitable for use when dealing with decision making in an educational setting, the potential pitfalls are many, and the practical experiences are still few. Now, before going into the use of the normative model in the teaching/learning about decision making on the waste issue, something has to be said about the meaning of the word 'normative'. The use of that word so far suggests that decision making *should* proceed along the broad lines set out by the normative model. In other words: if it does not proceed along those lines, the decision making should be considered at fault. However, in everyday life quite a lot of decision making goes astray from the normative model, whereas their results cannot be qualified as 'bad decisions'. To avoid further confusion, this normative meaning of the word 'normative' will be removed by changing the label of the associated decision making from normative to a more neutral one: *structured*.

In an educational setting the model of *structured* decision making could serve as a guideline for designing teaching/learning activities in which the students 'experience' such decision making, and in which these experiences are used to make the underlying decision-making procedure explicit. Such an explicit procedure might be considered by the students as a useful tool in their decision making on – to them new and complex – science/technology-related social issues, such as the waste issue and other issues emerging at a later stage in the curriculum. Making this decision-making procedure explicit, although not necessarily in the schematic form of figure 3.3, is therefore regarded as another aim of the teaching/learning process.

Decision making on the waste issue

In order to arrive at the educational aims of the teaching/learning process, the above outlined ideas about structured decision making are again useful, but far too general. The decision-making procedure represented by figure 3.3 has to be converted into a more specific procedure for decision making about the *waste issue*. This conversion concerns the conceptual input into this procedure. Given the earlier mentioned limitation of the contents to household packaging waste, the conceptual input into

the decision-making procedure should consist of knowledge about relevant environmental criteria for evaluating packaging alternatives and knowledge of criteria-related properties of packages and packaging materials.

The relevant environmental criteria can be drawn from the waste issue's structure in figure 3.2: the extent to which packaging alternatives contribute to *depletion* of resources and to *pollution* of soil, water and air – as these are the environmental problems connected to the waste issue that trigger the need for decision making from an environmental point of view. With this establishment of the relevant criteria, the required criteria-related knowledge about properties of packages and packaging materials can be specified in still general terms as knowledge about *renewability*, *recyclability*, *reusability* and *harmfulness* when dumped or burned in theory as well as in everyday life practice – as these properties determine the extent to which packaging alternatives contribute to depletion and pollution. In other words: knowledge about the trajectory of specific packages in the issue's structure of figure 3.2 during their 'life span'.

Now the ideas about a structure of the waste issue (limited to household packaging waste) and about a procedure for structured decision making have merged into ideas about an adequate body of issue knowledge as an aim of the teaching/learning process: knowledge about the structure of the waste issue is necessary for identifying the relevant environmental criteria for evaluating packaging alternatives. And in order to actually evaluate packaging alternatives on these identified criteria, knowledge about the criteria-related properties of packages and packaging materials is necessary.

3.3 Pre-knowledge and decision-making skill

For designing the teaching/learning process, the ideas about an adequate body of issue knowledge and an adequate decision-making procedure presented in the previous section are not enough. What is further needed is an idea about how the students' pre-knowledge and decision-making skill relate to what is thought to be adequate. In other words: which issue knowledge and decision-making skill do the students already have, and what has to be further addressed in the teaching/learning process?

Issue knowledge

The starting-point for students' learning about the waste issue is the assumption that they, set aside some specific issue-related terminology, do already have a rather complete body of general issue knowledge. It is assumed that they know in general about the production of packaging materials and packages, including an idea of the possible depletion of non-renewable resources. It is also assumed that they know about the processing of waste through dumping, burning, reuse and recycling,

including an idea of the possible pollution of air, water and soil in the case of dumping and burning. It is finally assumed that they recognise prevention, reuse and recycling as possibilities to counter depletion and pollution. The students' pre-knowledge thus 'covers' the structure of the waste issue as represented in figure 3.2. This assumption seems to be contrary to the findings in the phase of exploratory research and development concerning the NME-VO project's garbage unit as reported in chapter 2. However, as already hinted at in that chapter, the students' pre-knowledge might have been improperly interpreted. Taking the position of the students' pre-knowledge being coherent and sensible, it seems far more 'logical' and 'charitable' to assume that they already know all this stuff as a result of their everyday life experiences and preceding formal education, though perhaps not yet in the form of an explicit and coherent picture like the one in figure 3.2. In that case no more is needed than asking them, using as ingredients what they already know, to construct such a picture.

The two environmental problems in this picture naturally lead to the two relevant *environmental criteria* for decision making about packages: contribution to depletion of resources and to pollution of air, water and soil. It also shows the choice of raw material, prevention, reuse and recycling as practical possibilities to influence this contribution to depletion and pollution. And it even suggests that knowledge about the *criteria-related properties* of packages and packaging materials is needed for comparing packaging alternatives on the identified environmental criteria in the context of thoughtful decision making: which raw materials are renewable and which are non-renewable, which packages are reusable and which are non-reusable, which packaging materials are recyclable and which are non-recyclable, which packaging materials are harmful and which are non-harmful when dumped or burned? On the basis of the reported findings in the phase of exploratory research and development concerning the NME-VO project's garbage unit, it is reasonable to assume that the students' pre-knowledge in this area needs to be extended.

Decision making

The starting-point for students' decision making about the waste issue is the assumption that they, set aside some specific procedure-related terminology such as 'alternative' and 'criterion', do already have the skill of going through the decision-making procedure. It is assumed that they are able to identify a problem, to develop criteria and generate alternatives, to evaluate alternatives (through comparing generated alternatives on developed criteria), to choose the best solution (through a qualitative weighting of comparisons made), and to monitor new developments (regarding criteria and alternatives, in order to be able to recognise a change in decision-making situation). This is what they do – wittingly or unwittingly – in decision-making situations familiar and relevant to them in their everyday life. This is supported by the findings in the phase of exploratory research and development concerning the NME-VO project's garbage unit: without being told to do so, quite a number of students in their decision making do either implicitly or explicitly compare packaging alternatives on one and – in their thinking, but sometimes even

overtly expressed – more than one criterion. This is also in line with findings from another case-study on students' decision making about socio-scientific issues in science classes (Ratcliffe, 1997): an ability to identify suitable alternatives and criteria when using an explicit general decision-making procedure reflecting a criteria approach – although some difficulty in using the identified criteria systematically in reasoning. These findings seem to point at the desirability of offering students some (more) help in structuring their task of comparing the alternatives on the criteria.

So, as far as being able to use a criteria approach to decision making, there is not much for the students to learn: their decision-making skill is quite sufficient. This also implies that they will not perceive a criteria format for decision making somewhere in the teaching/learning process as being 'strange'. However, what is needed is the *conceptual input* into the decision-making procedure: knowledge about the relevant environmental criteria and knowledge about the criteria-related properties of packages and packaging materials – as identified earlier. Moreover, what is desired somewhere in the teaching/learning process is making the decision-making procedure *explicit*, e.g. in terms of figure 3.3. A conscious employment of such a decision-making procedure might be useful for students in a number of ways. It might facilitate the recognition of similarities and differences in decision making on different environmental and other science/technology-related social issues, especially in the area of developing (environmental and other) criteria. It might also facilitate decision making on other, new and complex environmental or other issues, as it points at the necessary information to be collected (about criteria and criteria-related characteristics of alternatives) and, of course, acts as a reminder of a way to process this information (comparing the alternatives on the criteria, and weighting these comparisons). Finally, it might also be of some help in presenting an argued point of view to others as completely and clearly as possible, as it stimulates a systematic collecting and processing of the necessary information.

Educational aims

Given the ideas about an adequate body of issue knowledge and an adequate decision-making procedure, and given the related assumptions about the students' pre-knowledge and decision-making skill, the educational aims of the teaching/learning process could now be specified as follows:

- the students know that depletion and pollution are the two relevant environmental criteria in decision-making situations about packages, and know the criteria-related properties of packages and packaging materials
- the students recognise that this knowledge is a prerequisite for decision making about packages, are able to use this knowledge in comparing packaging alternatives on the two environmental criteria, and are able to use these comparisons in presenting their argued point of view
- the students know that decision making can be structured in terms of a stepwise procedure (including the relevant environmental criteria and the necessary kind of knowledge), and at least suspect that this procedure is also useful for decision making on other environmental issues.

If these educational aims are reached, the students will be empowered for thoughtful decision making about packages, and will be prepared for tackling decision making on a broader range of environmental issues. Whether or not they want to contribute to 'a better environment', and whether or not they choose to act accordingly, is ultimately something they have to decide for themselves.

3.4 The teaching/learning process: a didactical structure

After having established *what* should be addressed in the teaching/learning process in the previous sections, the question now is: *how* should this be addressed? In other words: what kind of teaching/learning process is desired?

The findings in the first phase of exploratory research and development concerning the NME-VO project's garbage unit and the experiences in other developmental research projects of the *Centre of Science and Mathematics Education* (Cdβ) at Utrecht University (Klaassen, 1995; Vollebregt, 1998; Janssen, 1999) seem to point at the desirability of a *bottom-up* teaching/learning process: a sequence of teaching/learning activities designed on the basis of a profound knowledge of students' pre-knowledge and of its development, building on a proper interpretation of the students' knowledge as being coherent and sensible and using their constructions productively in a social process of the teacher's and students' coming to understand each other – as already suggested in chapter 1. According to this view the teaching/learning process should reflect a careful balance between 'freedom from below' (for the students) and 'guidance from above' (by the designed teaching/learning activities and the teacher). This asks for a design of the teaching/learning process meeting the following two requirements:

- The process is largely guided (from below) by the students' own motives, knowledge and questions in a problem-posing way, so that preferably they themselves come to frame the questions that drive their learning process.
- The process is structured (from above) by a sequence of interrelated teaching/learning activities, which starts from a proper interpretation of students' pre-knowledge and skill and carefully develops their motives, knowledge and questions as intended, given the educational aims of the teaching/learning process.

These ideas about the design of a *problem-posing* teaching/learning process will now be elaborated somewhat further, tuned to the teaching/learning of the specific topic of decision making about the waste issue.

A problem-posing approach

The core of a problem-posing approach to the teaching/learning about a specific topic could be summarised as "an approach whose emphasis is on bringing pupils in such a position that they themselves come to see the *point* of extending their existing conceptual resources, experiential base and belief system (with accompanying changes of meaning) in a certain direction." (Klaassen, 1995, p. 111). In designing

such a teaching/learning process for the topic of decision making about the waste issue, the following sequence of five interrelated teaching/learning activities or phases gradually emerged as a sensible and useful way of structuring the teaching/learning process for, at least, the topic under consideration: *motivation*, *question*, *investigation*, *application* and *reflection*. These five phases in the teaching/learning process will be characterised below, supplemented by some remarks about the crucial role of the teacher in helping his or her students to make their learning process explicit.

Motivation – The first phase in a problem-posing teaching/learning process has "to induce in pupils a sense of purpose for at least beginning to study the topic at hand, and to provide them with a first sense of direction concerning where their study will lead them to" (Klaassen, 1995, p. 112).

At the start of the teaching/learning process for the topic under consideration the students' *motive* would be their assumed willingness to contribute to 'a better environment' – however vague that may be for them. The students' decision-making *skill* is expected to reflect a criteria approach, although this decision-making procedure would be still implicit. The students' issue *knowledge* (about waste in general) is expected to be rather complete but still weakly structured, whereas their specific issue knowledge (about criteria-related properties of packages and packaging materials) would be still incomplete.

The students' motive of contributing to 'a better environment' could be used to have them identify a number of practical situations: everyday life personal environmental decision-making situations related to the use of water, energy and matter. An analysis of the similarities of these identified practical situations could be used to have them recognise packaging decision-making situations as being exemplary. This not only would provide the students with a more specific *motive* (contributing to 'a better environment' through decision making about packages) and thus a first outlook on their learning process, but would also induce an idea that what will be learned might also be applicable to decision making about (the) other environmental issues.

Question – The second phase in the teaching/learning process may then concentrate on making the students aware of a need for extending their knowledge in the light of the global motive, and letting them formulate this need in the form of their own *questions* for further investigation.

The students' more specific motive of contributing to 'a better environment' through decision making about packages asks for environmental criteria, expected to be established through having the students structure and reflect on their – for this purpose thought to be adequate – general issue knowledge (about household packaging waste). By having the students compare packaging alternatives on the established environmental criteria (depletion and pollution), they would come to realise that their structured general issue knowledge is inadequate for solving this decision-making situation, and that there is a need for extending their knowledge in the

direction of specific issue knowledge (about the criteria-related properties of packages and packaging materials).

In this phase of the teaching/learning process the students' general issue knowledge will have been structured – not as an aim in itself, but as a means for establishing the environmental criteria as an input into their decision making. The students' developing issue knowledge in the context of decision making is expected to have triggered a need to further extend their issue knowledge in a specific direction, in order to become able to solve the decision-making situation that provided an earlier motive for learning. This need of specific issue knowledge would be a new *motive*, expected to further drive the students' learning process.

In terms of the *educational aims* formulated in this chapter (section 3.3) what should have been reached so far after the motivation and question phases in the teaching/learning process is the first part of both the first and second aim: the students should know that depletion and pollution are the two relevant environmental criteria, and should recognise that knowledge about the criteria-related properties of packages and packaging materials is a prerequisite for decision making about packages. Moreover, the work still to be done for reaching the remaining part of these aims relating to knowledge acquisition and application has been prepared to quite some extent with the formulation of the questions for further investigation in the context of decision making about packages.

Investigation – The third phase in the teaching/learning process would then be one in which the students extend their knowledge by means of doing research of an either information-gathering or experimental nature, guided by the questions formulated in the preceding phase.

The new motive of finding answers to their questions for further investigation is expected to drive the students' learning process into extending their specific issue knowledge (about the criteria-related properties of packages and packaging materials), as this knowledge is thought to be adequate for solving the decision-making situation featuring in the second phase of the teaching/learning process. In addition to the already structured general issue knowledge, at the end of this phase the students' specific issue knowledge should be considered complete in the sense of adequate for decision-making purposes.

Application – A logical subsequent fourth phase in the teaching/learning process would then be one in which the students use their extended knowledge *for the purpose it has been extended for*.

During the preceding investigation phase the students were expected to have extended their knowledge for the purpose of decision making about packages. Or, more specific: for solving the decision-making situation featuring in the second phase of the teaching/learning process. Therefore, in the application phase the students will be asked to do just that: applying their extended knowledge to solve that decision-making situation. The result should be considered as an example of an

argued point of view, and could be further used productively for learning to present an argued point of view to others as completely and clearly as possible in a subsequent set of comparable packaging decision-making situations. This learning could concern the establishment of the desired characteristics of – or a set of 'rules' for – a clear presentation of an argued point of view.

In terms of the *educational aims* formulated in this chapter (section 3.3) what should have been reached now after the investigation and application phases is the remaining part of both the first and second aim: the students should know the criteria-related properties of packages and packaging materials, should be able to use this knowledge in comparing packaging alternatives on the two environmental criteria, and should be able to use these comparisons in presenting their argued point of view.

Reflection – The teaching/learning process might be concluded with a fifth and final phase in which the students reflect on the character of their extended knowledge and of the decision-making situations in which this extended knowledge could be useful.

The earlier recognised exemplary character of packaging decision-making situations should now offer the students another new *motive* for continuing their learning process: is what has been learned about decision making about packages also applicable to decision making about other environmental issues – as suspected earlier during the motivation phase. This would be the moment to make the decision-making procedure and its necessary knowledge input in terms of environmental criteria and criteria-related properties of packages and packaging materials explicit, by having the students reflect on their learning experiences so far. The earlier established analogy between everyday life personal environmental decision-making situations related to the use of water, energy and matter could then be used productively by the students to identify a suspected need for extending their criteria-related knowledge about other environmental issues.

In this final phase of the teaching/learning process the students' decision-making skill should have been made explicit in terms of a procedure for structured decision making – not as an aim in itself, but as a means for coping with other, new and complex environmental issues. The students' further developing issue knowledge in a specific direction and its successful application to decision-making situations in the preceding phases of the teaching/learning process is expected to have led to an idea about the necessary knowledge input into this decision-making procedure when dealing with these other environmental issues. This need of specific issue knowledge about a broader range of environmental issues could be considered a new *motive*, expected to further drive the students' learning process in a subsequent teaching/learning process.

In terms of the *educational aims* formulated in this chapter (section 3.3) what should now finally have been reached in the reflection phase is the remaining third aim: the students should know that decision making can be structured in terms of a stepwise

procedure (including the relevant environmental criteria and the necessary kind of knowledge), and should at least suspect that this procedure is also useful for decision making on other environmental issues.

Teaching/learning process – The above-described structure of the teaching/learning process suggests that the students will be provided with a clear view of their learning process. Or, in other words: provided with an idea of why they are learning what. It is not to be expected, however, that the students' view on their learning process would become fully clear without any help from the teacher. The role of the teacher in this respect would be one of stimulating the students at specific points in the teaching/learning process to reflect on why what has been done so far and to speculate on why what will be done next. So, a role of making the students' learning process more explicit to them, of letting them fully experience the fluency and coherence of their learning process. A structure as sketched above may help the teacher to do this. The start and the end of each of the five phases in the teaching/learning process, because of their coherence and distinct purpose, would provide 'natural' points for reflection.

The task of the teacher, however, is not only one of helping the students to make their learning process explicit, but also one of carefully guiding them through this learning process – of properly interpreting what students are putting forward in reaction to a specific task, of adequately questioning them with the aim of further clarification and elaboration, and of productively using their input for making a transition to the next task. This clearly reflects a fundamental change in the teacher's role from a transmitter of knowledge to a coach and facilitator – a change that appears to present teachers with considerable difficulties (Anderson, 1995a; 1995b; Hameyer *et al*., 1995; Black & Atkin, 1996). The idea of using a *scenario*, to be outlined in section 3.5 and further elaborated in chapter 4, was meant to facilitate the teacher in making the required change in classroom practice.

A didactical structure

In the above-outlined ideas about a problem-posing teaching/learning process the earlier mentioned ideas about an adequate body of issue knowledge, an adequate decision-making procedure and the students' pre-knowledge and skill have been fully incorporated. This description of the intended and expected teaching/learning process can be considered a – still hypothetical – *didactical structure* (Lijnse, 1995) for the teaching/learning about the specific topic of decision making on the waste issue. This didactical structure is summarised in figures 3.4 and 3.5, both organised vertically in terms of the five phases in the teaching/learning process and organised horizontally in terms of the students' motive, waste issue knowledge and decision-making still. Figure 3.4 is meant to indicate the students' initial situation and the educational aims that should have been reached at different points in the teaching/learning process. Figure 3.5 is meant to summarise the interaction between the students' initial and developing motive, issue knowledge and decision-making skill that drives their learning process.

phase	motive	waste issue knowledge	decision-making skill
	contributing to 'a better environment'	general: weakly structured specific: incomplete	procedure: implicit criteria: unknown
motivation question			
	extending specific waste issue knowledge	general: structured specific: incomplete	procedure: implicit criteria: known
investigation application reflection			
	extending specific water/ energy issue knowledge	general: structured specific: complete	procedure: explicit criteria: known

Figure 3.4 – A (hypothetical) didactical structure for the teaching/learning of decision making about the waste issue, indicating the students' initial situation and the intermediate and final educational aims with respect to motive, waste issue knowledge and decision-making skill.

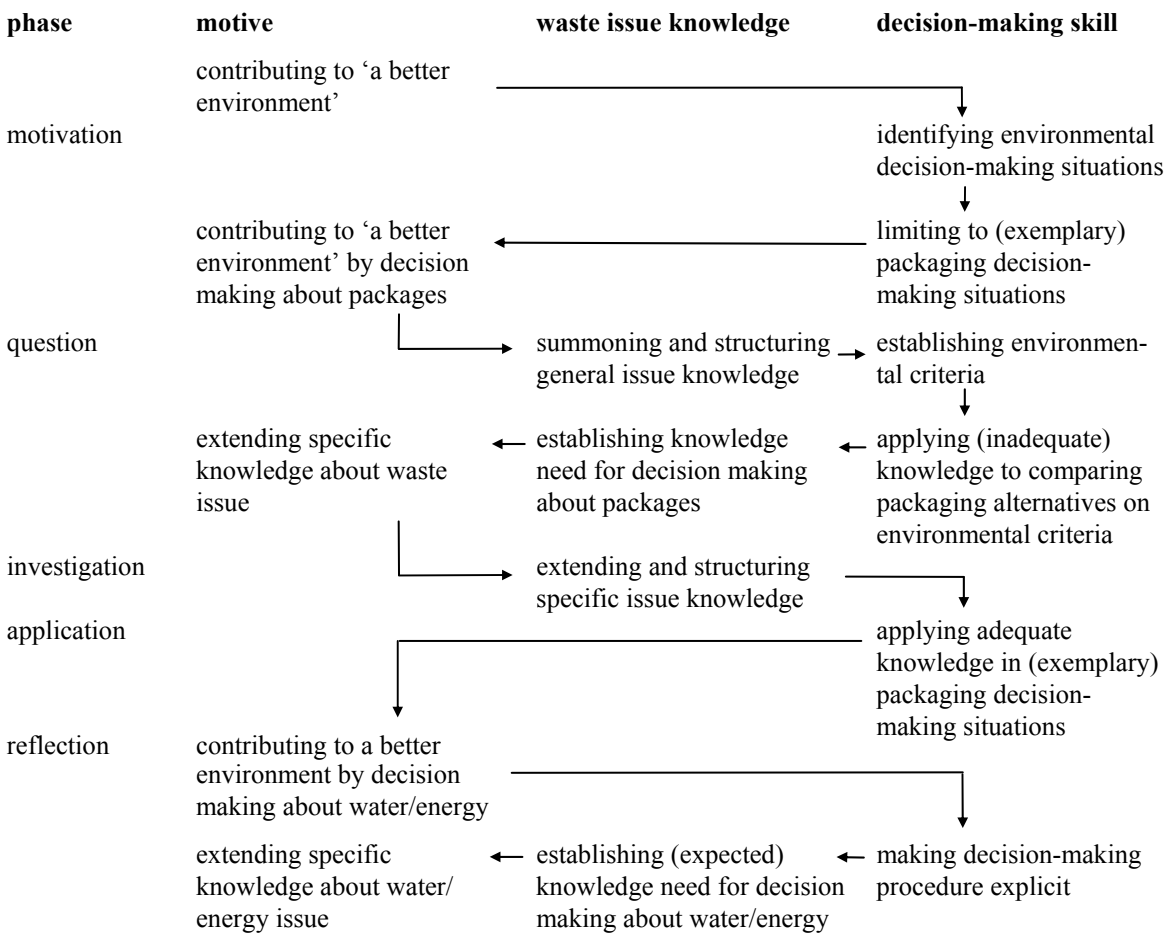


Figure 3.5 – A (hypothetical) didactical structure for the teaching/learning of decision making about the waste issue, indicating the interaction between the students' existing and developing motive, issue knowledge and decision-making skill.

Interactions

Now that the didactical structure has been outlined, it is possible to reflect on two important aspects: the students' existing and developing motives that are supposed to drive their learning process, and the motives-driven interaction between the development of the students' waste issue knowledge and decision-making skill.

Motives – With respect to motives the teaching/learning process seems to consist of two distinctive parts. The first part consists of the first two phases: the *motivation* and *question* phases. In these phases the students' global motive of contributing to 'a better environment' should be narrowed down to the specific motive of extending their waste issue knowledge in a specified direction, by productively using the students' existing waste issue knowledge and decision-making skill. This specific motive, expressed by the students' own questions for further investigation, should further drive their learning process during the second part, especially in the *investigation* and *application* phases. In the *reflection* phase of the teaching/learning process this specific motive would be reconnected to the earlier global motive when the students tentatively consider the usefulness of their learning experiences for decision making about other environmental issues. At this point new specific motives of extending their knowledge about, e.g., the water and energy issues in a specified direction should start emerging.

Issue knowledge and decision-making skill – With respect to the motives-driven interaction between the development of the students' waste issue knowledge and decision-making skill the teaching/learning process seems to split up into the same two distinctive parts.

In the first two phases of the teaching/learning process the interaction between *motives*, *issue knowledge* and *decision making* is quite complicated. The students' decision making seems to present a kind of backbone to the teaching/learning process. At first it could be seen as an operationalisation of the students' initial motive to contribute to 'a better environment', necessitating the structuring and subsequent productive use of their general issue knowledge. Somewhat later in the teaching/learning process it would provide the students with the more specific motive to further drive their learning process. It should be noted that for the time being nothing much would be 'learned' in the traditional sense, with the exception of the explicit recognition of the two environmental criteria for decision making about packages. Most of the time will be taken by productively using the students' initial motive, issue knowledge and decision-making skill to arrive at a motive and a direction for the students to extend their issue knowledge. So, to define why what has to be learned.

During the last three phases of the teaching/learning process the interaction between *motives*, *issue knowledge* and *decision making* is less complicated. Again, the students' decision making seems to present a kind of backbone to the teaching/learning process. The motive that should drive the students' learning process into extending their criteria-related issue knowledge has been derived from earlier

decision-making experiences (in the second phase of the teaching/learning process), and their extended knowledge therefore would serve as an input into related decision making. At the start of this second part of the teaching/learning process the focus thus would be on extending the students' issue knowledge. The focus then would shift towards their decision-making skill, first in terms of insightfully applying their extended issue knowledge to waste-related decision-making situations, and secondly – at a more abstract level – in terms of establishing the desired characteristics of a clear presentation of the resulting argued point of view. A reflection on their subsequent (successful) decision-making experiences in terms of making the underlying decision-making procedure and its required knowledge input explicit would then provide them with a tool for tackling further decision making about other environmental issues.

The above characterisation of the didactical structure shows that the way in which the educational aims in the areas of issue knowledge and decision making are expected to be reached are closely intertwined from the start until the end of the teaching/learning process. This close connection between what in general terms might be called knowledge acquisition and skills development could be summarised as follows: a start with an emphasis on knowledge acquisition in the context of decision making, gradually shifting towards an emphasis on skills development in the area of decision making with the help of the acquired knowledge.

3.5 Developmental research

The ideas presented in the preceding section could be considered a *first attempt* at designing a didactical structure. So, a first step in a process of developmental research indicated in chapter 1. This first step of what might be called 'theoretical reflection' (as opposed to 'practical reflection', e.g. on classroom experiences) has to be followed by curriculum development and teacher preparation, and classroom research of the interaction of teaching and learning processes – with the aim of providing an empirical basis for the hypothetical didactical structure.

The process of developmental research not only starts with ideas about the didactical structure, but also with ideas about the *research design* and about the *tools* to use in order to keep the process of developmental research on track.

Research design

The research design is one of in-depth, small-scale and qualitative developmental research in two successive experimental groups of students at the same school and taught by the same teacher. This is considered to be enough to provide an empirical basis for the hypothetical didactical structure. Only if the designed didactical structure in the end appears to be 'good enough' under these limited and controlled circumstances, it becomes useful to extend the research into a large-scale, quantitative and comparative direction – but that has not been done (yet). Developmental

research aims at a product (a theory-based didactical structure) that in principle 'should work', but of which the effectiveness in a variety of classroom situations still has to be tested. However, this testing then concerns a carefully designed and pre-tested product and not a product with all kinds of 'infant diseases' muddling the interpretation of research findings. Moreover, the experiences during the preceding cycles of developmental research can be used productively for adequately preparing the trial teachers for this further testing of the product.

The scenario

A critical element in the research design is the idea of a *scenario* (Klaassen, 1995) as a tool for designing the specific teaching/learning activities and the even more specific student tasks these activities consist of, for preparing the teacher on the classroom trial, for focusing the classroom observations during the trial, and for guiding a post-trial reflection on the question whether or not the designed didactical structure could be considered 'good enough'.

Designing teaching/learning activities – Designing a problem-posing teaching/learning process at the general level of activities and especially at the more detailed level of student tasks these activities consist of is not easy at all. Some kind of designer tool would be helpful. One such tool could be the *scenario*, to be developed alongside and in interaction with the development of the student materials. This scenario can be seen as an explicit description of the desired and expected teaching/learning process.

A first step in writing the scenario would be to give an explicit idea of the educational aims and of the students' existing motives, pre-knowledge and skills to build productively upon. And further: to give a justification and general outline of the teaching/learning process concentrating on the students' existing and developing motives, knowledge and skills. This first step roughly reflects what has been done in sections 3.2 up to and including 3.4 in this chapter: designing a hypothetical didactical structure.

The second step in writing the scenario would then be to elaborate these general ideas into the more detailed tasks each phase of the teaching/learning process consists of. This can only be done in interaction with actually writing the student materials, frequently switching from scenario to student materials and vice versa. In the end the student materials contain the tasks, while the scenario gives a justification of these tasks in terms of how one task builds on the preceding one and prepares for the next one, a description of what the students and the teacher are expected to do, and an expectation about the outcomes of each task. These expectations are, on the one hand, based on what reasonably or logically might be expected given the structure and sequence of the tasks, and, on the other hand, based on earlier research findings (e.g., from student interviews) or on earlier experiences (e.g., classroom trials of a preceding – intuitively developed – version of the teaching/learning unit). In writing the scenario and the student materials these expectations about the outcomes of each task are considered to be crucial, because the character and the

outcomes of the next task will be dependent on the outcomes of the preceding task. Or, in other words: a specific task cannot be written without a grounded assumption about the outcomes of the preceding task and an idea about the intention of the next task. The scenario and the student materials thus become a detailed *design* of the desired and expected teaching/learning process in the classroom. However, this is not to say that in classroom practice this process should proceed exactly along the lines specified in the scenario. Minor deviations from the scenario as a result of the students' unforeseen reactions are certainly allowed, and might even be necessary to maintain the fluency and coherence of their learning process. So, the actual teaching/learning process in the classroom could be slightly oscillating around the desired and expected process as written down in the scenario.

Pre-trial teacher preparation – The completed scenario gives an extensive description of the ideas behind the teaching/learning process, the intention and interrelatedness of its phases and tasks within these phases, the way they are expected to be carried out, and the expected outcomes of each task. This would provide valuable material for the teacher to prepare him- or herself for the trial. In this way the completed scenario could be considered as a rather detailed teachers' guide, to be used in the teacher's pre-trial preparation.

On-trial classroom observations – Putting the designed teaching/learning process to the test in classroom practice by a prepared trial teacher is of no use without careful classroom observations. But what to observe? Just going into the classroom 'to see what happens' quite often is not very informative without having a clear idea of 'what is supposed to happen'. Moreover, that 'what happens' quite often has to be reconstructed in hindsight. In that case there is no opportunity for a real-time influence on the course of the teaching/learning process.

The scenario is helpful in answering the question of what to observe, as the scenario prescribes what is supposed to happen in the classroom in the interaction between teacher and students and what the outcomes of this interaction are supposed to be. Or, in other words: the scenario for each successive task presents an assumption about the outcomes of the task under certain conditions. The classroom observations can therefore focus on the question whether or not these conditions are fulfilled to a sufficient degree, and, if so, whether or not the outcomes roughly turn out to be as assumed. In this way the classroom observations have a clear purpose of collecting data for either confirming or rejecting the scenario's assumptions in the course of the teaching/learning process. As a result of this specific focus of the classroom observations a major deviation from the intended teaching/learning process in classroom practice can now more easily and quickly be signalled, and in due course amended by conferring with the teacher – in an, of course, unobtrusive way.

Post-trial reflection – The scenario's hypothesised teaching/learning process also guides the post-trial reflection on its quality. Major discrepancies between the intended and observed teaching/learning process necessarily represent serious points

for reflection: where did the observed teaching/learning process 'go astray', and why did this happen – were certain conditions as described in the scenario not met in classroom practice, were the scenario's assumptions about the tasks' outcomes asking too much or too little from the students, did the teacher forget something important or was the scenario unclear about what he was supposed to do or say, etc.?

This kind of reflection on the intended teaching/learning process as described in the scenario and the observed teaching/learning process in classroom practice prepares the way for thinking about the necessary revision of the scenario and the student materials in the next cycle of developmental research: what can be done about what went wrong? And, of course, the modifications of the scenario and the student materials in the design phase of this next cycle of developmental research also could serve as focal points for the teacher's pre-trial preparation, the on-trial classroom observations and the post-trial reflection.

3.6 Preview

The ideas presented in this chapter about a *didactical structure* for teaching decision making about the waste issue, and the use of a *scenario* for elaborating and testing it, are meant to prevent the errors made during the phase of exploratory research and development described in chapter 2: an underestimation of the didactical problems and an inadequate view on teaching/learning processes. However, these ideas represent nothing more than a *hypothetical* didactical structure and a *potentially* useful tool. The following chapters 4 up to and including 6 will therefore deal with the *product*, the *process* and the *test*, respectively.

The *product* described in chapter 4 is the (for the time being final) teaching/learning unit used in the second cycle of developmental research. Chapter 4 thus focuses on *processing the raw materials* dug up in this chapter 3 into a product: the scenario and student materials. The *process* dealt with in chapter 5 tries to describe 'the unit in the making' during the first cycle of developmental research on a selected number of crucial aspects: the (in)validity of the hypotheses about the students' issue knowledge and decision-making skill, the design of the teaching/learning process (and the structural design errors revealed by its classroom trial), the (in)adequacy of the preparation of the teacher on the classroom trial, and the modifications thought necessary to arrive at the improved second version as described in chapter 4. Chapter 5 thus focuses on *recycling* and *reusing* the ideas about and experiences with the unit's first version. Subsequently, chapter 6 reports about putting this improved version to the *test*: what did happen during the classroom trial during the second cycle of developmental research, is the didactical structure 'good enough', and, if not, what further modifications might be necessary? And by the way of a sneak preview: the answer to this question of the didactical structure being 'good enough' is … yes, in general, but no-not-yet as far as specific important elements of the scenario and classroom practice are concerned.

4 The product: a teaching/learning unit for decision making about the waste issue – processing the raw materials …

4.1 Introduction

The developmental research has gone through two complete cycles. The purpose of this chapter is to describe the *product* of the phase of curriculum development in the *second* cycle. It describes the designed scenario and student materials in its second version, in which the experiences during the *first* cycle (to be described to some extent in chapter 5) have been assimilated. As far as the *scenario* is concerned, the description could be characterised as being an on *intermediate* level – intermediate between, on the one hand, the rather general level at which the teaching/learning process has been described in chapter 3, and, on the other hand, the rather detailed level at which the intended and expected outcomes and connected classroom procedures have been described for the practical purposes of preparing for, carrying out and evaluating the classroom trials. So, this chapter presents an *abstract* of the quite extensive scenario. However, such an abstract might obscure the crucial role of the teacher in guiding the students through their learning process. Therefore, at some points in the outline of the teaching/learning process the teacher's expected input will be specified by a full reproduction of the relevant part of the scenario. As far as the *student materials* are concerned, the description consists of a full reproduction of the tasks from the students' workbook. The additional reference materials and worksheets provided to the students in connection to some of the tasks have not been included.

The outline of the scenario, the connected tasks from the students' workbook and the examples of the teacher's expected input into the teaching/learning process are presented in the sections 4.2 up to and including 4.6. They deal with each of the five phases of the teaching/learning process identified in the previous chapter: motivation, question, investigation, application and reflection.

4.2 The motivation phase: inducing a global motive

The first teaching/learning activity has to induce in students a sense of purpose for at least beginning to study the topic at hand, and to provide them with a first sense of direction concerning where their study will lead them to. The *motivation* phase in the unit therefore induces a *global motive* for beginning to study the waste issue – and more specific: decision making about packaging waste.

General outline

The assumption is that students are willing to contribute to what they themselves might call 'a better environment'. In this sense the topic of the unit relates to an assumed existing motive of the students. For at least a portion of the students, however, a global motive limited to contributing to 'a better environment' through choosing between packaging alternatives probably will not be 'strong' enough, because this contribution will be perceived by them as rather limited. During the motivation phase in the unit, therefore, a broader range of action perspectives should be summoned, together with the idea that contributing to 'a better environment' by choosing between packaging alternatives is *exemplary* for the possibilities in other areas as well. Suitable areas in this respect may be the use of water and energy in and around the house, given the similarities regarding the extraction of 'something' from the environment (raw material, water and fuel) and (later, at a different site) the addition of 'something' (waste) to the environment. This should then lead to the presumption that 'learning something' about choosing between packaging alternatives could also be of use for decision making in the other environmental areas (of water and energy use), and thus strengthen the global motive. After having done this, it should be possible to provide the students with a global outlook on their learning process: see whether we know enough for being able to make an environmentally sound choice between packaging alternatives, and, if not, assess and acquire the lacking knowledge and use the acquired knowledge in waste-related decision-making situations (during the question, investigation, and application phases in the unit, respectively), and see in what way these experiences can be made use of in other environment-related decision-making situations (during the reflection phase in the unit).

Specific tasks

This general outline of the character of the motivation phase in the unit has been converted into the tasks reproduced in figure 4.1, representing the first teaching/learning activity labelled *A better environment ...*in the students' workbook. Each of the tasks is meant to be tackled by the students through small-group work, giving them the opportunity to prepare their input into an ensuing teacher-led whole-class discussion.

Task 1: Decision-making situations – The first task introduces a number of social and personal decision-making situations, some of which are environment-related. The purpose of this task is to focus the students' attention on personal decision-making situations in which they themselves could contribute to something like – in their own terms, and still unspecified – 'a better environment'. This task thus gives them an idea of the character of the decision-making situations featuring in the unit, and also – assuming their inclination to contribute to 'a better environment' – provides them with a point for studying those.

Task 2: Environmental decision-making situations – In this second task the students

analyse the personal environment-related decision-making situations identified by them in task 1. The purpose of this task is to establish the similarities of the identified decision-making situations as far as the human interventions of extraction from and addition to the environment are concerned. This expected outcome prepares the students for the next task, in which this range of decision-making situations for the time being is going to be limited to packages. The identified similarities should elicit the idea that package-related decision-making situations (as a specific case of extraction of raw materials from the environment and of addition of waste to the environment) could very well be exemplary for the range of environment-related decision-making situations. This idea should be made explicit by the teacher in the transition from task 2 to task 3, connecting to what has been put forward by the students in the foregoing classroom discussion.

Task 3: Packaging decision-making situations – This task makes the limitation to decision-making situations about packaging explicit. The purpose of this task is to make students realise that even in such a limited area the number of decision-making situations is higher than probably expected, and that the environment is only one of the points to consider in decision making. In this way the limitations as well as the perspective of what is going to be learned may become clear. It is then possible for the teacher to give a preview – based on what has happened in classroom practice so far – of what will happen in the remainder of the series of lessons.

These three tasks of the motivation phase in the unit not only prepare the students for studying the topic in general, but also partly provide a more specific preparation. The expected outcome of task 2 also prepares the students for their giving a better definition in the unit's next phase of what exactly 'a better environment' is – a definition that appeared to remain vague throughout the trial of the unit's earlier version in the first cycle of developmental research.

Activity 1

A better environment ...

1 Decision-making situations

Figure 1 below presents nine decision-making situations. Such a situation deals with making a *choice* between different *alternatives*.

- Which of the decision-making situations in figure 1 have something to do with the *environment*? Encircle the appropriate numbers.
- And in which of these decision-making situations can you, through *your own* choice, contribute to *a better environment*? Colour the appropriate encircled numbers.

---

1 A new railway track for the 'high-speed-train' between Schiphol Airport and Rotterdam has to be constructed. Does the new track has to go right

through or to circumvent the ‘green zone’ in the circle of cities in this part of the Netherlands?

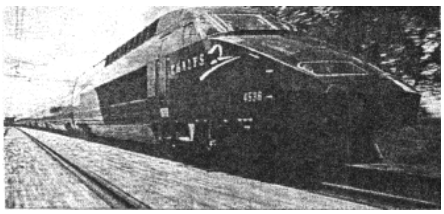


Figure A – High-speed-train.

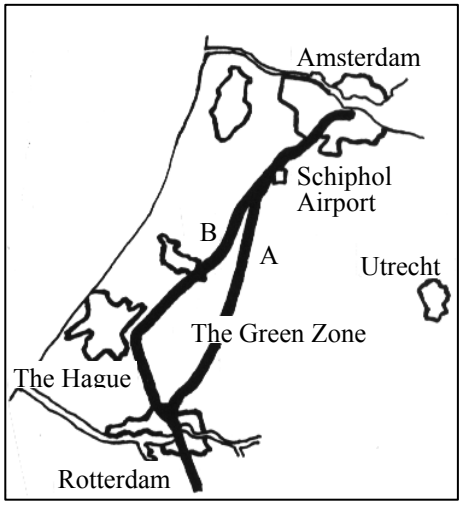


Figure B – Two possible new railway tracks: right through (A) or circumventing (B) the green zone in the circle of cities.

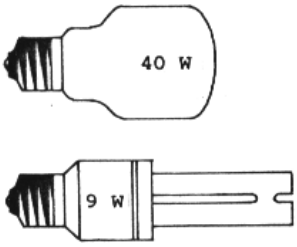


Figure C – Filament bulb (above) and energy saving lamp (below).

2 You wish to wash yourself. Do you take a bath or a shower?

3 The accident rate of mopeds is quite high. Should moped drivers first have to pass an exam, or not?

4 The filament bulb above your desk has broken down. Do you replace it by a new filament bulb or an energy saving lamp?

5 After your birthday you still have a few cd vouchers. Which cd are you going to buy?

6 Your bicycle has now become too small. You are getting a new one. You can choose between a bike with a drum brake and three gears and a bike with rim brake and ten gears. Which one do you choose?

7 The flight traffic at Schiphol Airport gets more and more busy. Has a fifth runway to be constructed, or not?

Figure E – Milk in bottles and cartons.

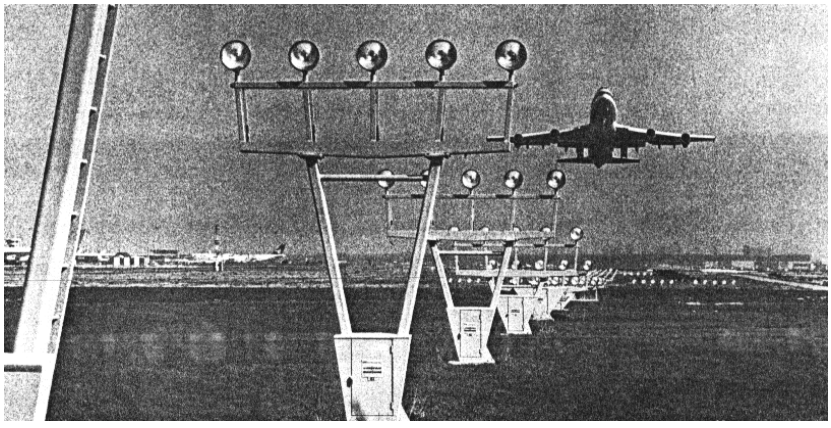


Figure D – Plans for a fifth runway at Schiphol Airport.

8 The shopping list says you have to buy milk. In the shop milk is available in plastic bottles and in cartons. Which package do you choose?

9 You have to buy a new pocket calculator. The same calculator exists in two kinds: one is powered by a battery and the other by a solar cell. Which calculator do you buy?

Figure 1 – Decision-making situations

2 Environmental decision-making situations

There are decision-making situations in which you, through *your own* choice, can contribute to a better environment. Choose one of these situations from figure 1. And for that situation, answer the following four questions.

- In this decision-making situation, what are the two *alternatives*? And do you know other alternatives?
- Has this decision-making situation to do with the use of *material*, or with the use of *water*, or with the use of *energy* (natural gas or electricity)?
- Where does this material, water or energy come from?
- Does the use of this material, water or energy produce *waste*? And if yes: what kind of waste? And where does this waste go to?

3 Packaging decision-making situations

Environmental decision-making situations have to do with the use of material, water or energy. An example is choosing between *packaging alternatives*: different packages for the same product.

- In which of the decision-making situations from figure 1 can you contribute to a better environment through your choice between packaging alternatives?
- Do you know other examples of decision-making situations concerning packages? If yes: what is the product? And what are the packaging alternatives for this product?
- In those situations, which other points besides 'a better environment' play a part in making a choice?

Figure 4.1 – Student material: the tasks of the motivation phase in the teaching/learning unit.

Teacher input

From the above description of the motivation phase in the unit it becomes clear that the task of the teacher is threefold: guiding the whole-class discussions about the questions put forward in the tasks, taking care of the transitions between the tasks, and occasionally stimulating a retrospection on what has happened so far and providing a preview of what will happen in the remainder of the series of lessons.

The way in which the teacher could perform these tasks is described in quite some detail in the scenario – a 'detail' that regrettably was not included in the scenario used during the first cycle of developmental research. An example is given in figure 4.2: the full scenario for tasks 2 and 3 of the motivation phase in the unit. This scenario describes the hypothetical teaching/learning process in quite some detail. It tells the teacher how to perform his or her tasks, though a certain degree of flexibility is needed as the teacher is expected to connect to what is being and has been put forward by the students. This might slightly (and at times even considerably) differ from what has been assumed in the scenario. This is the main reason why

the task of making the transition from one task to the next is left to the teacher. Including such transitions in terms of a text connecting the two tasks in the students' workbook would reduce the necessary flexibility to zero. Moreover, such a text would easily 'give away' the answers to the questions put forward in the preceding task. This would certainly not stimulate some 'independent thinking' on the part of the students in preparing their input into the ensuing whole-class discussion.

So, looking only at the tasks making up the student materials such as those in figure 4.1 could easily give one (including the students) the impression that these tasks are unconnected, while they certainly are not – as should have already become apparent in the accessory elucidation and is even more clearly expressed by the example of the full scenario reproduced in figure 4.2. For the reasons given above it is the teacher – aided by the scenario – who is asked to 'continuously' help the students in making them 'see' the *local coherence* of their learning process by taking care of the transitions between the successive tasks.

Task 2	**Environmental decision-making situations**
Purpose	• Identifying the similarities between personal environment-related decision-making situations: 'something' (raw material, water, fuel) is extracted from the environment, and 'waste' (empty packages and batteries, sewage water, exhaust gases) is added to the environment (later, at a different place).
Introduction	• In task 1 you have found decision-making situations which have something to do with the environment, and in which you yourself have a choice. Now, as a group choose one of those decision-making situations (number encircled and coloured), and answer the questions in task 2 for that decision-making situation.
Working method	• Small-group work, followed by informal reporting and whole-class discussion. The student groups can choose one out of the four identified decision-making situations. Check whether or not all four decision-making situations have been chosen, and – if necessary – ask volunteers for the non-chosen decision-making situation(s). After the small-group work, ask for one informal student report (so, not in front of the class) for each decision-making situation, with an opportunity for comments/amplification by other groups that have dealt with the same decision-making situation.
Results	• The students have no difficulty in identifying the alternatives and the type of use: material (decision-making situations 8 and 9), water (2) or energy (4 and 9). • The answers to the question of where this material, water and energy comes from will probably be rather concrete and 'near-home-like': (packaging, battery and solar cell) plant, water and power plant etc. In that case further questioning is needed: 'Where does that plant get that material/water/natural gas from?', 'How does the power plant produce electricity? Where does that plant get its fuel from?' etc. In the course of this further questioning it has to become clear that in all cases 'something is being extracted from the environment'. • Concerning the answers to the questions about waste, probably something comparable will happen: empty packages and batteries, and (finally) broken down solar powered calculators disappear in the garbage bag or container,

	waste water goes into the sewer, and the exhaust gases of the heating system or power plant disappear through the chimney into the air. In that case further questioning is needed: 'Where does the garbage truck go? What happens there with the garbage? Does burning empty packages produce waste? What happens with that waste?', 'Where does that sewage water go?' etc. The students will probably have no difficulty in stating that the use of material (for packages, batteries and solar powered calculators) and water produces waste, but it is questionable whether or not this also applies to the use of natural gas/electricity – the waste (exhaust gases) in this case is rather invisible. Also then further questioning is needed: 'Does burning natural gas (in the heating system) produce waste? Why (then) do we need a chimney?', 'The use of electricity at home does not produce waste, but what happens at the power plant where this electricity comes from?' etc. In the course of this further questioning it has to become clear that in all cases 'some kind of waste is added to the environment'.
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] If there is an environment-related decision-making situation in which you – as a consumer – have a choice, then this relates to the use of material, water and energy (natural gas/electricity). This is stuff we need to keep ourselves alive. And we extract that stuff from the environment: raw materials from the crust of the earth, water from rivers and lakes (or ground water), and energy (natural gas, coal for power plants) again from the earth's crust. And during or after use we dump the waste at a different place in the environment: in the soil, the water and the air. So, from an environmental point of view those different decision-making situations are similar – we extract stuff from the environment, and add the waste (in a different place) to the environment. Now, in task 3, let's have a closer look at one of these decision-making situations: a packaging decision-making situation ...
Time	• 10'
Task 3	**Packaging decision-making situations**
Purpose	• Identifying packaging decision-making situations and the other points (besides 'a better environment') to consider in decision making – followed by a preview of what will happen in the remainder of the series of lessons.
Introduction	• Which of the decision-making situations in task 1 is an example of such a [packaging decision-making] situation?
Working method	• Whole-class discussion. After the answer to the first question, show both packages and if necessary introduce the concept of *packaging alternative*: this milk bottle is one packaging alternative, and this milk carton is the other packaging alternative – two different packages for the same product (milk).
Teaching aids	• Empty packages: milk bottle and carton.
Results	• The students will select decision-making situation 8 as one related to packaging. • The students will have no difficulty in identifying other packaging decision-making situations (can/jar, bottle/can etc.) and other points to consider in decision making (price, comfort, ease, taste etc.)
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] So, there is quite a number of points to consider when making a choice (between packaging alternatives). But in this series of lessons we will mainly deal with packages and the environment: for those products that can be bought in different packages (and we have seen that there are a lot of those) find out which packaging

	alternative would be the best choice if you want to contribute to a better environment. In order to be able to make such a choice, we first have to find out about what exactly do we mean with 'a better environment' and whether we know enough about the environmental impact of packages (activity 2 – referring to the contents of the students' workbook). And if it appears that we do not yet know enough, then we have questions to which we have to try to find an answer by doing research (activity 3). With those answers we then can make a thoughtful, argued choice between packaging alternatives (activity 4). And finally we will then have another look at the other decision-making situations (activity 5). Because we have seen that decision-making situations about packages, water and energy are similar. And so, what we learn about choosing between packaging alternatives might also be useful for tackling those other decision-making situations (about water and energy).
Time	• 05'

Figure 4.2 – Scenario: the hypothetical teaching/learning process throughout tasks 2 and 3 of the motivation phase in the unit.

4.3 The question phase: establishing a knowledge need

In the second teaching/learning activity the students should become aware of a need for extending their knowledge in the light of the global motive, and formulate this need in the form of their own questions for further investigation. The question phase in the unit therefore continues with giving students an idea of what 'learning something' about choosing between packaging alternatives might be – as a second, but now more specific preview on their learning process.

General outline

Giving the students a more specific preview on their learning process requires a specification of the still rather vague notion of 'a better environment'. Such a specification can be arrived at by letting the students elicit and structure their existing everyday life knowledge about production of materials and waste processing: the dumping and burning of packaging waste causes depletion of raw materials for the production of packaging materials and causes pollution of air, soil and water by hazardous waste. So, for making an environmentally sound choice, the packaging alternatives have to be compared on two environmental criteria: depletion and pollution. With this specification of 'a better environment' it is possible to provide the students with a sharpened preview of their learning process: learning something – if necessary – about depletion of raw materials for the production of packaging materials and about pollution by dumping and burning packaging waste.

After this specification the students will have to become aware of a need for extending their knowledge about packages and packaging materials in the light of the global motive: for being able to contribute to less depletion and pollution through choosing between packaging alternatives, our knowledge about packages and packaging materials is not adequate yet. And consequently students will have to

formulate this perceived need for extending their knowledge in terms of questions for further investigation: what are (in theory and in practice) the possibilities for countering depletion and pollution regarding the most frequently used packaging materials?

During this phase in the unit it is important that students get the idea that an answer to these questions enables them to make an environmentally sound choice between packaging alternatives. And anticipating the search for answers to these questions during the unit's next phase it must become clear, again by reflection on their existing everyday life knowledge, that the possibilities for countering depletion and pollution relate to the renewability of resources, prevention of unnecessary packaging, reuse of packages and recycling of packaging materials.

Specific tasks

This general outline of the character of the question phase in the unit has been elaborated into the tasks reproduced in figure 4.3, representing the second teaching/ learning activity about *Packages and the environment* in the students' workbook. Again, each of the tasks is meant to be tackled by the students through small-group work, giving them the opportunity to prepare their input into an ensuing teacher-led whole-class discussion. And again, one of the teacher's tasks is to make the relationship between successive tasks explicit in the introduction and conclusion of each task.

Task 4: Wrapping up and packing off – In this task the students are asked to watch a short video about (packaging) waste, as a follow-up to the restriction of the topic arrived at in the preceding task 3. The purpose of this task is to continue the specification of 'a better environment' as prepared in task 2. This is done by having students watch the video, guided by questions about the environmental problems caused by the use of packages and the solutions to these problems. An additional purpose of showing them the video is to visualise the different ways of waste processing, which normally take place out of their sight. It is assumed that students, on the basis of their existing everyday life knowledge triggered by the audio-visual information, will identify pollution as an environmental problem, and prevention, separate collection of hazardous household waste, reuse of packages and recycling of packaging materials as solutions to this problem. Some careful questioning by the teacher in the whole-class discussion following the video, using paper as an example of waste and referring to the students' answers in task 2, is expected to also summon the idea of depletion of raw materials as an environmental problem. During this whole-class discussion a small collection of carefully chosen empty packages can be used to also clarify concepts such as prevention, hazardous household waste, reuse and recycling. It is in this task that the students' existing everyday life issue knowledge, as assumed in chapter 3 (section 3.3) is being elicited. After some structuring of this existing issue knowledge in the next task, it can be used productively for having the students frame the questions that will further drive their learning process.

Task 5: Summary – This task summarises the 'bits and pieces' of waste issue knowledge put forward by the students during the whole-class discussion of the preceding task 4. The purpose of this task is to structure the students' existing everyday life knowledge by constructing a model of the waste issue. This is done by asking the students to solve a kind of jigsaw puzzle, and write a short story about what the puzzle's solution represents. The puzzle's solution as reproduced in figure 4.4 is roughly identical to the model of the waste issue in figure 3.2. It is expected that students will be able to construct this model by themselves, guided by the puzzle format of the task. This constructed model prepares the required specification of contributing to 'a better environment' featuring in the unit's motivation phase, and prepares the transformation of this specification into environmental criteria for making a choice between packaging alternatives in the next task. Moreover, this model once again clearly shows that prevention, separate collection of hazardous household waste, reuse of packages and recycling of packaging materials may influence the degree of depletion and pollution – which will play a part in formulating the questions for further investigation in task 9.

Task 6: A better environment ... – After constructing the model of the waste issue, this task represents a reflection on what has been constructed. Its purpose is to specify contributing to 'a better environment' into contributing to 'less depletion and pollution'. This is done by asking the students to look back at their model of the waste issue constructed in the preceding task 5, guided by the following question: which points do you have to pay attention to if you want to contribute to 'a better environment' through choosing between packaging alternatives? It is assumed that the model's structure is appropriate for this purpose of specification. The specification in turn prepares the students for the next task, in which packaging alternatives will be compared on the two environmental criteria.

Task 7: ... starts with choosing a package – The 'points to pay attention to' from the preceding task 6 are first, in order to provide a common language, defined as being *environmental criteria*. The purpose of this task is to elicit a need for more knowledge about packages and packaging materials in the context of the global motive established in the unit's preceding phase: in order to be able to contribute to less depletion and pollution through choosing between packaging alternatives, we do not yet know enough about packages. This need for extending their knowledge is summoned by presenting the students with an example of a decision-making situation (milk bottle/carton), and by asking them to compare these packaging alternatives on both environmental criteria. This connects to the students' existing decision-making skill, as assumed in chapter 3 (section 3.3), to either implicitly or explicitly compare alternatives on criteria. It is expected that through careful questioning by the teacher in the ensuing whole-class discussion *disagreements* between students about these comparisons or instances of simply *not knowing* will emerge: is the bottle reusable or recyclable, is the carton recyclable, does the carton contribute to pollution when dumped or burned, is the renewability of wood as the raw material for paper enough

for not contributing to depletion, etc. These questions are not to be discussed at length, but should be noted as 'things we have to know about packages and packaging materials' before being able to compare them on the environmental criteria with the intention of making an environmentally sound choice, thus preparing the formulation of questions for further investigation in task 9 – something that did not work out too well during the first cycle of developmental research.

The students' identification of a knowledge need in task 7 represents a key feature of a problem-posing teaching/learning process, given that this knowledge need is supposed to further drive their learning process. Task 7 is therefore crucial. It is prepared in the preceding tasks by defining the packaging-related decision-making situations featuring in the unit and by establishing the environmental criteria on which packaging alternatives should be compared. The full scenario for task 7 is reproduced in figure 4.5, showing what is expected from the teacher in helping the students to arrive at the intended identification of their knowledge need on the basis of their attempts at comparing packaging alternatives on the established environmental criteria.

Task 8: Packaging materials – A second preparation for formulating the questions for further investigation takes place in task 8: if we have to know more about packaging materials, then *which* packaging materials do we have to know more about? The purpose of this task is to have students identify the five most frequently used packaging materials, if necessary with the help of a collection of empty packages. It is expected that students will quickly identify paper/carton, glass, (tin-plated) steel, aluminium and plastic as such.

Task 9: Research questions – The final task during this question phase in the unit represents a reflection on the preceding tasks. Its purpose is to have students summarise the established need for extending their knowledge in the form of questions for further investigation: what is (in theory and in practice) the contribution to depletion and pollution of the five most frequently used packaging materials? It is assumed that the preceding tasks will have prepared the students for this task to a sufficient degree, and that the formulated questions are sufficiently matched to the investigation in the unit's next phase.

The question phase in the unit can now be concluded by looking back at the decision-making situation of task 7: if we can find an answer to the questions for further investigation, we will certainly be able to tackle packaging-related decision-making situations such as the one about milk in a bottle or carton. And, shifting into a preview: first we are going to find those answers, and next we are going to use these answers in decision-making situations about packaging (during the investigation and application phases in the unit, respectively) – a perspective that now, given the decision-making context from which the questions for further investigation have originated, sounds quite 'natural', but was obscured by clouds of lengthy and partly superfluous tasks in the unit during the first cycle of developmental research.

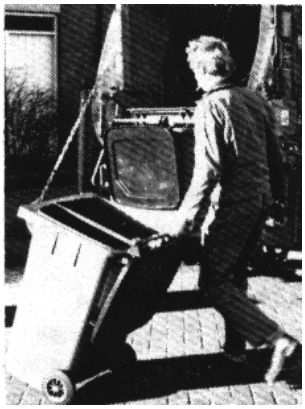
Activity 2

Packages and the environment

4 Wrapping up and packing off

By making a choice between packaging alternatives you can contribute to a better environment. But then you have to know which environmental problems packages can give. And which solutions exist for those problems.
Watch the video *Wrapping up and packing off*. Then answer the following two questions.

- What happens with packaging waste going into the garbage bag or container? And which environmental problems could this give rise to?
- Which solutions exist for these environmental problems?



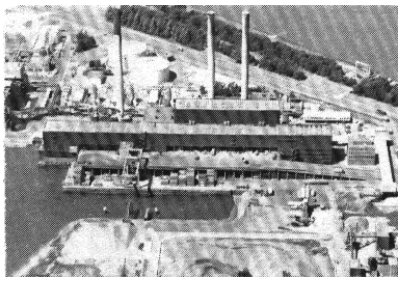
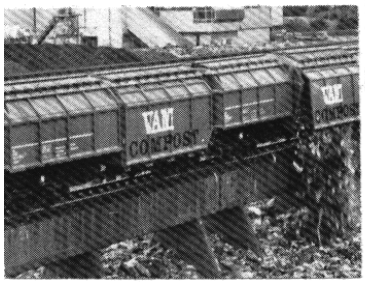


Figure 2 – When shopping you do not only buy products, but also packages. Some of those packages at a later time end up in the household garbage. The sanitary department collects this garbage (left). Then the garbage is transported to a dumping site (middle) or an incinerator (right).



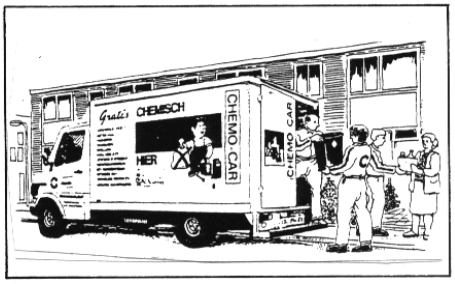


Figure 3 – Part of the household waste does not end up at the dumping site or in the incinerator. The organic waste is collected separately and processed into compost (left). Also the hazardous 'chemical household waste' is collected separately (right).

Figure 4 – Part of the empty packages is still useful in one way or another. Those packages go back to the shop for reuse (left). Or they go into special containers for paper and glass recycling (right).

5 Summary

Now you know which *environmental problems* packages can give rise to. And which solutions exist for these problems. You are going to visualise that in one scheme. That you do by solving a puzzle.
Figure 5 already gives part of the solution. Take the worksheet with the remainder of the puzzle's pieces. Cut out those pieces.

- Complete the puzzle in figure 5 by fitting in the remainder of the puzzle's pieces. When all pieces are in the right place, fasten them with some glue.
- On a separate sheet write a story about the puzzle's solution: explain what the scheme shows.

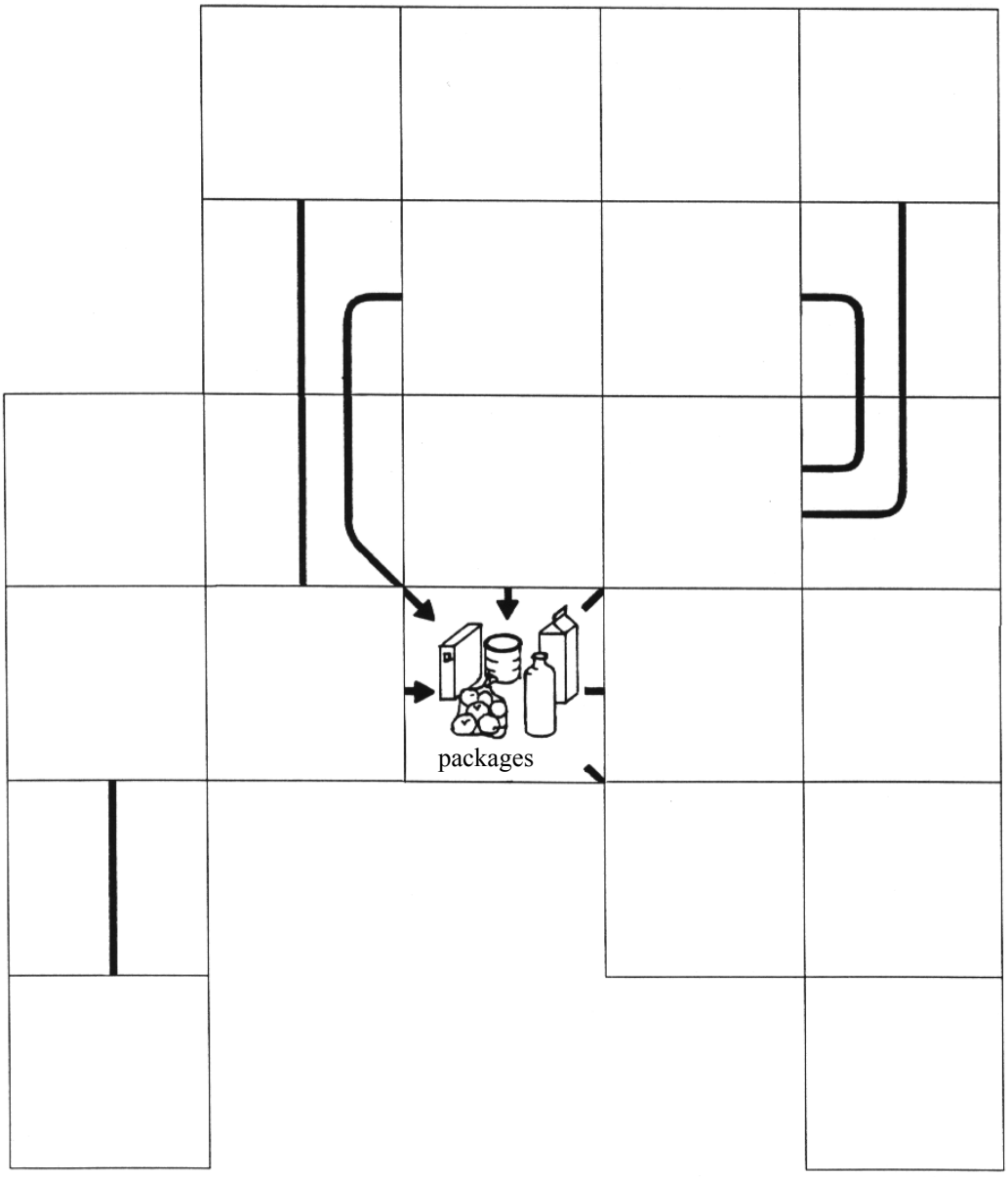


Figure 5 – Scheme of the life cycle of packages

6 A better environment …

By choosing between packaging alternatives you can contribute to a better environment. But: 'a better

environment', what exactly do we mean by that ...

- Look at the puzzle's solution in figure 5: which two environmental problems can packages give? *And so*: to which two points should you pay attention when choosing between packaging alternatives?

7 ... starts with choosing a package

The points to pay attention to when choosing between packaging alternatives we call *environmental criteria*.

- The table of figure 6 presents a decision-making situation: milk in a plastic bottle or in a carton. Write down in the table which materials these packages are made of. Then write down the two environmental criteria in the table's first column.
Compare the two packages on the first environmental criterion: which package is 'better for the environment' on that criterion, and why? Write this down in the table's second column. Then compare the two packages in the same way on the second environmental criterion.

product	milk	
packaging alternatives	bottle	carton
packaging materials	……..	……..
environmental criteria	comparison	
……	……	
……	……	

Figure 6 – Bottle/carton decision-making situation

8 Packaging materials

When comparing packaging alternatives on the two environmental criteria you have noticed that we need to know more about packaging materials. But: *which packaging materials* do we need to know more about ...

- Look at the collection of empty packages in the classroom: which materials are these packages made of? Write down below the five most frequently used packaging materials.

- Look around in your neighbourhood shop, in the supermarket and in the food storage at home. Do you find any other frequently used packaging materials? So: materials different from those you have already written down? If so: which?

9 Research questions

By choosing between packaging alternatives you can contribute to 'a better environment'. Then you have to compare those packaging alternatives on the two environmental criteria. But: then you need to know more about the five most frequently used packaging materials.

- Write down below what you need to find out about those packaging materials. Or, in other words: what your *research questions* are.

Figure 4.3 – Student material: the tasks of the question phase in the teaching/learning unit. The students' worksheet with the remainder of the puzzle's pieces has been left out. The puzzle's solution is reproduced in figure 4.4.

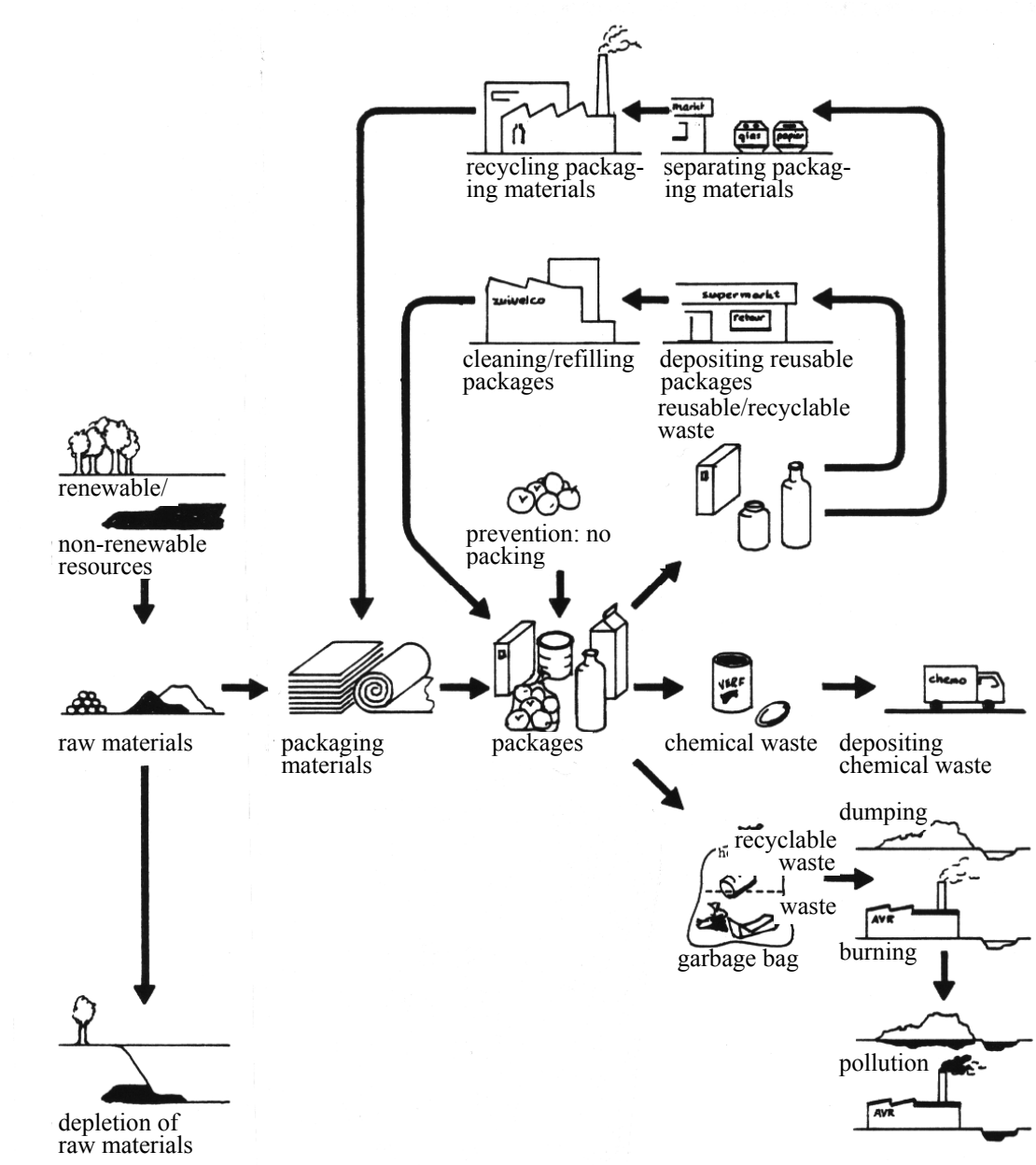


Figure 4.4 – Student material: the students' solution of the puzzle in task 5, representing the model of the waste issue limited to household packaging waste.

Task 7	**... starts with choosing a package**
Purpose	• Eliciting a knowledge need: for choosing between packaging alternatives we have to know more about the properties of packages/packaging materials – as a preparation for formulating the questions for further investigation in task 9.
Introduction	• We now know [from task 6] which points to pay attention to if we want to contribute to a better environment through a choice between packaging alternatives. These environmental criteria are: less depletion/pollution. Here I

	have two packaging alternatives for the product milk: a plastic bottle and a carton [show packaging alternatives to the class]. Now, in task 7, let's try to compare those two packages on the two environmental criteria – in order to find out whether we already know enough for being able to make a choice ... that's what we have agreed upon at the end of activity 1: first find out what we mean with 'a better environment' – and that's what we now know – and then find out whether we know enough about the environmental impact of packages.
Working method	• Small-group work, followed by whole-class discussion.
Teaching aids	• Empty packages: milk bottle and carton.
Results	• It is expected that students will not reach agreement on the comparison of the two packaging alternatives on the two environmental criteria – as a result of either simply 'not knowing' or disagreement. On the environmental criterion of depletion the bottle will probably raise uncertainty: it may be reusable, but for how many times and what happens afterwards – is plastic recyclable or is the decrepit bottle being dumped or burned? As a result of this uncertainty it remains unclear whether the raw material for plastic (and which raw material is that?) could run out, apart from the question whether or not that raw material is 'renewable' in one way or another (just like the raw material for paper/carton: wood). And with respect to the carton: carton is recyclable, but then why are empty milk cartons not to be put into the waste paper recycling container – is the carton of milk cartons then maybe not recyclable and is it being dumped or burned or maybe afterwards separated from the remainder of the garbage for recycling – and if it is being dumped or burned, could wood as the raw material for paper/carton 'grow up' quick enough? All of this apart from the question which material the 'carton' of a milk carton consists of: carton or carton with a thin layer of plastic against leakage? On the environmental criterion of pollution comparable questions will emerge: are these packages (ultimately) being dumped or burned, and are they then hazardous or not? It is expected that students – in the case of dumping/burning – will qualify these materials (plastic/'carton') as hazardous. Doubts about this qualification could be raised by referring to task 5: 'Hazardous (household chemical) waste is being collected separately – and if milk cartons would be hazardous when dumped/burned, then why do those cartons not belong to the category of household chemical waste?' Or by a question on an elementary and for students recognisable function of packages: 'Why do we pack (food) products? And would such a package then be allowed to be hazardous?' • During the whole-class discussion the questions have to be put forward as much as possible by the students themselves, by asking them to present their comparison of the two alternatives on a criterion and to comment, complement and question the comparisons presented by others. Not all of the above mentioned questions have to come forward: it is sufficient if the whole-class discussion on each of the two environmental criteria results in establishing that 'we do not yet know enough about the packages/packaging materials for being able to make a choice'. So, the whole-class discussion should not be continued/guided up to the point of having reached an agreement about the two comparisons.
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] When comparing the packaging alternatives we run into a problem: we don't know enough about those materials. We don't know enough, or we don't agree. So, there are questions, e.g. about that milk bottle: is plastic recyclable, could the raw material for

	plastic run out, is plastic hazardous when dumped or burned? And regarding the carton: which materials does the carton consist of (or: carton is recyclable, but does that also apply to a carton with thin layers of plastic), what about depletion of raw materials and pollution when dumped or burned? Those are questions about the properties of packaging materials. And we'll have to find an answer to those questions before being able to make a sound choice between packaging alternatives. The same kind of questions will probably turn up for the other packaging materials (which we have not yet encountered in this task). Therefore, the question in task 8 is: the properties of which packaging materials do we have to know more about?
Time	• 15'

Figure 4.5 – Scenario: the hypothetical teaching/learning process throughout task 7 of the question phase in the unit.

The teaching/learning process along the lines of the scenario in the first two phases of the didactical structure is expected to take roughly two classroom periods of 45 minutes each.

4.4 The investigation phase: extending knowledge

In the third teaching/learning activity the students extend their knowledge by means of an investigation, guided by the questions formulated during the preceding phase in the unit.

General outline

The students extend their knowledge through using written and audio-visual reference materials, interviewing experts and performing experiments. This knowledge concerns the criteria-related properties of packages and packaging materials. More specifically, this knowledge relates first of all to depletion of resources for the production of packaging materials, including the raw materials from which packaging materials are being made, the renewability or non-renewability of these raw materials, and an estimate of the size of each resource and its rate of decrease (or increase) over time. Secondly, it relates to pollution through dumping and burning of packaging materials, taking into account the separate collection and processing of household chemical waste. And thirdly, it relates to reusing and recycling of packages and packaging materials either or not after separate collection, including a distinction between the potential and actual practice of separate collection and reuse/recycling. In all three cases this knowledge will have to concern each of the five most often used packaging materials.

During this phase in the unit it is of some importance that all students structure their newly acquired knowledge in such a way that it is 'ready for use' in the unit's next phase.

Specific tasks

This general outline of the character of the investigation phase in the unit has been converted into the tasks reproduced in figure 4.6, representing the third teaching/ learning activity of *Investigating packages* in the students' workbook.

Task 10: Research – In this task students are asked to collect and process information about the five most often used packaging materials in the audio-visual and written reference materials available to them as a part of the unit. The purpose of this task is that students get an overview of the relevant information for answering the questions for further investigation formulated in task 9 from the unit's preceding phase. The questions in this task, on the one hand, clearly refer to these questions for further investigation, and, on the other hand, help the students to find the relevant information in the audio-visual and written reference materials. It is expected that students will experience no problems with collecting the required information during a period of small-group work, as all of these data are available to them in the rather structured reference materials. For the students this period may also be a welcome interruption of the pattern of alternating small-group work and rather intensive whole-class discussions in the foregoing lessons.

Task 11: Summary – After completing task 10 the students are supposed to have an overview of information pertaining to the waste-related properties of packages and packaging materials. But that is not identical to the criteria-related properties featuring in the questions for further investigation of task 9. This transition is made in task 11, representing a reflection on the outcomes of the preceding task 10. The purpose of this task is to have students summarise the collected information in such a way that it represents an argued answer to the question about the contribution of each of the five most often used packaging materials to depletion and pollution – as shown in the full scenario for this task reproduced in figure 4.7. At the same time, and quite logically given the decision-making context of task 7 from which these questions have originated, this expected result of task 11 has a format which is ready for use in the decision-making situations featuring in the unit's next phase.

This in itself would be enough for directly continuing with the application phase in the unit. However, after all the hard work done by the students on tasks 10 and 11, why don't we give them a kind of well-deserved though, of course, also useful break?

Task 12: Additional research – This break consists of a number of optional subtasks of interviewing experts and performing experiments for small-group work. These subtasks are meant to clarify and/or illustrate the information provided by the written and audio-visual reference materials on certain points, but also to achieve a variety in the character of the unit's tasks and the students' working methods. Each group of students reports the results of the interview or experiment orally to the rest of the class. This prepares the students for the oral reporting required at some point during the unit's next phase.

Activity 3

Investigating packages

10 Research

In task 9 you wrote down your research questions. In this task you are going to find an answer to these questions.

- In the table of figure 7 the five most often used packaging materials are listed. For each packaging material, write down in the table:
  - which raw material is needed for producing the packaging material
  - whether or not this raw material is renewable
  - which size the supply of a non-renewable raw material has
  - whether or not the packaging material presents a hazard when dumped
  - whether or not the packaging material presents a hazard when burned
  - whether or not the packaging material is recyclable
  - which portion of the packaging material is recycled in practice.

Use the written and audio-visual reference materials available in the classroom for finding the answers to these questions.

	paper/carton	glass	tin-plated steel	aluminium	plastic
• raw material(s)	…… ……	…… …….	…….		
• renewability of raw material(s)	…….				
• availability of raw material(s)					
• hazard of material when dumped					
• hazard of material when burned					
• recyclability of material					
• recycling practice	…… …..				

Figure 7 – Data of packaging materials

11 Summary

In task 10 you have searched for an answer to the research questions. In this task you are going to summarise that answer in a table.

- The table of figure 8 lists the five most often used packaging materials. For each packaging material, write down in the table:
  - whether or not *in practice* there is *depletion* of raw materials, and why
  - whether or not *in practice* there is *pollution* through dumping or burning, and why.

	in practice yes/no depletion of raw materials, because …	in practice yes/no pollution through dumping/burning, because …
• paper/carton • glass • tin-plated steel • aluminium • plastic	…… ……	…….

Figure 8 – Data of packaging materials

Figure 4.6 – Student material: the tasks of the investigation phase in the teaching/learning unit. The (written) reference materials to be used in task 10 and the text and worksheets of task 12 are not included.

Task 11	**Summary**
Purpose	• Summarising the knowledge about packaging materials extended through research, in a format which is ready for use in comparing packaging alternatives on the two environmental criteria.
Introduction	• Let's see in task 11 if we can reach agreement about such a summary [of the research results in task 10], so that we can use the table of figure 8 during the oncoming activity 4 in making a choice between packaging alternatives.
Working method	• Whole-class discussion.
Results	• The expected result in terms of the table of figure 8 [in the student material] is given below. This result originates by putting the task's questions to the students.

	depletion of raw materials	pollution by dumping/burning
paper/carton	no: raw material renewable and supply constant, limited recycling[1)]	no: material not (very) harmful – except for heavy metals in printing ink and traces of chlorine[2)]
glass	no: raw materials non-renewable, but vast supplies and extensive recycling	no: material non-harmful
tin-plated steel	yes: raw materials non-renewable and (yet) limited recycling (by separation after disposal)	no: material non-harmful
aluminium	yes: raw material non-renewable and (yet) very limited recycling	no: material non-harmful
plastic	yes: raw material renewable, but supply decreasing and (yet) very limited recycling[3)]	no: material non-harmful – except for chlorine in PVC[4)]

[1)] No recycling of carton/plastic laminate
[2)] Use of heavy metals in printing ink and use of chlorine for bleaching both decreasing
[3)] Recycling limited to plastic returnable packages
[4)] Little or no use of PVC for packaging any more

A point of attention during the whole-class discussion is the difference between the contribution of using the different packaging materials to

	depletion and pollution in theory and in practice. In completing the table one should deal with the contribution in current practice. Because only that has relevance for comparing packaging alternatives in activity 4. The difference between theory and practice does also have some relevance there, but at a somewhat later stage: in identifying future developments that might give rise to a new decision-making situation. The difference between theory and practice, however, is also expressed by the wordings in the table.
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] Now we've got an answer to our questions for further investigation. However, before we are going to use those answers for making a choice between packaging alternatives (in activity 4), there might be things you want to know more about (such as: what happens with decrepit returnable packages?), things you might want to check (such as: is PVC really not used for packaging any more, and are milk cartons really non-recyclable?), or things you would just like to see (such as: how does recycling glass and paper go about, and how are tin-plated steel and aluminium recovered after disposal?). You will be able to find out in task 12.
Time	• 15'

Figure 4.7 – Scenario: the hypothetical teaching/learning process throughout task 11 of the investigation phase in the unit.

4.5 The application phase: using extended knowledge

In the fourth teaching/learning activity the students apply their extended knowledge from the preceding investigation phase for the (also to them quite clear) purpose it has been extended for: tackling the decision-making situations introduced in the motivation phase and further specified in the question phase. So, the application phase of the unit deals with decision-making situations about packaging.

General outline

During this phase in the unit it must be(come) clear that the extended knowledge is indeed useful for formulating an argued point of view, first in an already known decision-making situation (the bottle/carton decision-making situation featuring in activity 2) and secondly in decision-making situations to be identified by the students themselves. Orally reporting their argued point of view in a self-identified decision-making situation to the class stimulates students to present their argued point of view as clearly as possible, and offers the opportunity to make the desired characteristics of a clear presentation explicit.

During this phase in the unit it is of some importance that the students are offered some help in structuring their task of comparing both (or all) alternatives on both environmental criteria.

Specific tasks

This general outline of the character of the application phase in the unit has resulted

in the tasks reproduced in figure 4.8, representing the fourth teaching/learning activity of *Comparing packages* in the students' workbook.

Task 13: Decision-making situations: carton/bottle – This task offers the students the opportunity to apply their knowledge as extended in task 11 to the already familiar bottle/carton decision-making situation of task 7: which packaging alternative contributes to less depletion and pollution, and under which new (or: future) conditions would that choice turn out differently? This last point has to make clear that the result of decision making (that is: a decision) is nothing more than a sign of the times: future developments (e.g., different alternatives, new recycling options) can make the result of going through the same decision-making procedure turn out differently. The purpose of this task is to have students experience that their extended knowledge is indeed – as expected – sufficient for enabling them to continue their decision making interrupted earlier in task 7. The students' use of their extended knowledge in this decision-making situation is structured by some specific questions about the packaging materials, the relevant environmental criteria, the comparison of alternatives on these criteria, the choice of the best alternative based on these comparisons, and the potential new conditions necessitating a revision of the choice made.

The result of a whole-class discussion about the comparisons and choices put forward by the students is assumed to represent an example of an *argued point of view*, thus preparing students for the more open-ended decision-making exercise in task 15.

Task 14: Weighting – This task provides an additional reflection on the outcome of the preceding decision-making exercise. Its purpose is to show (again, because this also has been done in activity 1) that making such a choice always involves other than environmental criteria too. The required weighting of the comparisons made on all these criteria might result in a decision different from the decision made in task 13 on the basis of the environmental criteria only.

Task 15: Choosing packages – The decision-making exercise of task 13 has its follow-up in task 15, again offering students the opportunity to apply their extended knowledge – in this case to a self-chosen packaging decision-making situation. The purpose of this task is, firstly, that students identify such a decision-making situation and, secondly, that they structure their decision making along the lines set out in task 13 (without being explicitly told to do so). It is expected that at this point of the teaching/learning process students will be able to identify a decision-making situation in terms of realistic packaging alternatives, to compare these alternatives correctly on the two environmental criteria, and to choose the best alternative from an environmental point of view – if necessary after a weighting of the comparisons made on each of the criteria. The subtask of preparing an oral report to the whole class is supposed to stimulate the students to present their argued point of view as clearly as possible.

Task 16: Reporting – In this task the students are asked to present their decision-making reports to the whole class, and to react to what is being put forward by their fellow students. The purpose of this task is to establish some characteristics of a clear presentation of an argued point of view in a situation of communicating with others about the decision made. It is expected that students will at first have difficulty in communicating their argued point of view. However, this offers the opportunity for fellow-students to comment, if necessary guided by careful questioning by the teacher. In this way the characteristics of a clear presentation of an argued point of view might gradually develop in the course of a number of successive classroom reports towards something like a clear reproduction of the alternatives and criteria, a systematic reproduction of the comparison of the alternatives on the criteria, and an explicit reproduction of the choices per criterion, the weighting of these choices and the final choice. A development, that is, towards a set of 'rules' for a clear presentation of an argued point of view, which reflect the consecutive steps in the decision-making procedure – something that clearly did not succeed during the first cycle of developmental research.

Developing the intended characteristics by the students themselves is prepared in task 15 by, firstly, referring to the example of an argued point of view as the result of their work on task 13, and, secondly, by instructing them 'to try to explain *as well as possible* which choice they have made and why' in their self-chosen decision-making situation during their report to the class. The full scenario for task 16 is reproduced in figure 4.9, showing what is expected from the teacher in helping the students to arrive at the intended characteristics of – or a set of 'rules' for – a clear presentation on the basis of their reports to the class.

Activity 4

Comparing packages

13 Decision-making situation: carton/bottle

In task 7 you have tried to choose between two milk packages: a plastic refundable bottle and a carton. Then you noticed that you did not yet know enough for being able to make that choice. But now you know more about these two packages ...

- Compare these two packages on the two environmental criteria. For doing this, use the table of figure 10.
- Consider the comparison of the packaging alternatives on the two environmental criteria in the table of figure 10. What seems to be the best packaging alternative, if you through your choice want to contribute to 'a better environment'?
- Now you have made a choice about the best packaging alternative for milk. Is this a choice that is made once and for all? Or, in other words: what future developments would force you to reconsider your choice?

product	milk	
packaging alternatives	bottle	carton
packaging materials	……..	……..
	……..	……..

environmental criteria	comparison
……	……
	……
	…….
……	……
	……
	……..

Figure 10 – Bottle/carton decision-making situation

14 Weighting

In task 13 you made a choice between packaging alternatives. To do that, you have compared the packaging alternatives on the two environmental criteria. But most of the times there are also other criteria involved in making a choice ...

- Which other criteria could you also compare the packaging alternatives on?
- If you also compare the packaging alternatives on these other criteria, will the choice you make then differ from the one you made in task 13? Explain why.

15 Choosing packages

In task 13 you made a choice between packaging alternatives for milk. Now you are going to look for *another* decision-making situation ...

- Look around in the neighbourhood shop, the supermarket or the store-cupboard at home. Search for examples of a product that is on sale in two (or more) different packages. Choose one of these products. Describe the *decision-making situation* you have chosen.
- Give an *argued point of view* about the best packaging alternative in that decision-making situation. In doing that, you only have to consider the *environmental criteria*.
- Prepare a *presentation* about this task. You will get a couple of minutes to tell the class about the decision-making situation. Maybe you can show the packaging alternatives. Try to explain *as well as possible* which choice you have made, and why.

16 Presentation

In task 15 you made a choice between packaging alternatives ...

- Deliver your presentation about this task. And listen carefully to the presentation of your fellow-students: what is their decision-making situation, which choice do they make, and which arguments do they have? When listening to their *argumentation*, consider what you think are the *strong* and the *weak* points.
- What points do you have to pay attention to when putting forward your argued point of view *as well as possible*?

Figure 4.8 – Student material: the tasks of the application phase in the teaching/learning unit.

Task 16	**Presentation**
Purpose	• Practising in presenting and discussing an argued point of view to/with others (fellow students), and – on the basis of those discussions – identifying some desired characteristics of a clear presentation of an argued point of view.
Introduction	• Each group has prepared a brief presentation about a self-chosen decision-making situation. Take your time for delivering your presentation: we're not in a hurry. First indicate clearly what the decision-making situation is, and then give the argumentation. Talk loud and clear. And for those who are listening – be quiet and pay attention to what they are saying: consider what you think are the strong points and the weak points in their argumentation and why. After each presentation you can ask them questions about things that you have not yet understood, and give your comments on their argumentation.
Working method	• Students' presentations and whole-class discussion.
Results	• It is expected that students are now fairly well able to present an argued point of view in packaging decision-making situations, and to comment on the presented argued points of view – although not yet perfectly well. As a starter for identifying the desired characteristics of the presentation of an argued point of view the following questions can be put to the class (if the students do not put forward these questions by themselves): 'Have the two or more packaging alternatives been described clearly? On which environmental criteria have these alternatives been compared? Are those the relevant (two) environmental criteria? Are those comparisons complete (in the sense of: related to both or all alternatives) and correct?' • Making a choice is difficult if the packaging alternatives score differently on the two environmental criteria. If students do not make a choice in such a situation: ok. But a question then could be: 'Is it clear why no choice is being made?' And if the reporting students do make a choice, then a question about the consistency could be asked: 'Does that choice fit the expressed weight of the different environmental criteria?' • After having 'reviewed' a number of presentations in this way, the desired characteristics of the presentation of an argued point of view could be identified by putting this as a question to the class. The result – after further questioning, if necessary – could be something such as: a clear description of the decision-making situation, a correct and complete comparison of the packaging alternatives on both environmental criteria (depletion and pollution), and – if possible on the basis of those comparisons – a clear choice that fits the comparisons made. This could be complemented with another desired characteristic in case the alternatives score differently on the two environmental criteria: an indication of why a choice cannot be made, *or* an indication of the importance attached (by the students) to the different environmental criteria and a fitting choice.
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] Now you have learned quite a lot about packaging decision-making situations: we now know which points to pay attention to when presenting an argued point of view – and we now roughly know what we have to know/do to arrive at such an argued point of view: that's what you yourself have done a couple of times already, using your knowledge about packages (the environmental criteria from activity 2 and the related properties of packages from the research in activity 3). So, you're able to tackle packaging decision-making situations. Now let's see whether what we've learned about packaging decision-making situations also

	in one way or another applies to other environmental decision-making situations, such as those about water and energy from the start of the series of lessons (activity 1).
Time	• 40’

Figure 4.9 – Scenario: the hypothetical teaching/learning process throughout task 16 of the application phase in the unit.

The decision-making exercises in this application phase might have presented the students with the difficulty of weighting the environmental criteria in the case of ‘conflicting outcomes’. That is, if the preferred alternative on the criterion of depletion is different from the preferred alternative on the criterion of pollution. Then one has to consider the relative importance or weight of both criteria in order to be able to choose the best alternative. This might have students wondering whether there exists an ‘objective’ way of weighting these conflicting outcomes. If the students express such a question, it might be concluded that the extended knowledge is not yet sufficient for enabling such weighting. This would represent the emergence of a question for further investigation of the waste issue at maybe a more quantitative level of life cycle analysis of packaging alternatives. Such a question is clearly relevant, but should be set aside for the time being to be dealt with at a later stage in the curriculum – if possible.

The teaching/learning process so far has reflected the consecutive steps of a procedure for structured decision making and the acquisition of the required knowledge input into this procedure: identifying packaging decision-making situations (activity 1), developing environmental criteria and identifying the needed criteria-related knowledge about packaging alternatives (activity 2), acquiring this knowledge (activity 3) and using it in decision making about packages (activity 4). With this, the teaching/learning activities 1 up to and including 4 prepare for making the decision-making procedure and its knowledge input explicit in the next (and final) reflection phase of the unit.

4.6 The reflection phase: reflecting on extended knowledge

In the fifth and final teaching/learning activity the students reflect on their decision-making experiences relating to the decision-making procedure and the character of their extended knowledge required for going through this procedure, and tentatively explore the usefulness of these experiences in the light of the global motive induced during the first phase in the unit.

General outline

During this phase in the unit the students make the decision-making procedure and its required knowledge input explicit by reflecting on their learning experiences concerning decision making about packages during the preceding phases in the unit. The students then tentatively explore whether these learning experiences could be

useful in other environmental decision-making situations in which contributing to decreasing (the increase of) depletion and pollution is a possibility.

The reflection on the learning experiences about decision making is to bring forward the decision-making procedure, the relevant environmental criteria, and the character of the required knowledge for comparing alternatives on these criteria. Furthermore, the students are to get the idea that this general knowledge would facilitate thoughtful decision making in other areas, such as water and energy issues. They then might suspect that the decision-making procedure in those cases can be gone through more quickly, as it is now (more) clear what the environmental criteria are, which kind of knowledge is needed, and in which way this knowledge can be used in decision making. They then might also suspect that they are better able to do this decision making (more) independently. In the reflection phase, however, such a preview on a continued teaching/learning process is limited to formulating preliminary questions for further investigation concerning water and energy issues.

Specific tasks

This general outline of the character of the reflection phase in the unit has been converted into the tasks reproduced in figure 4.10, representing the fifth teaching/learning activity in the students' workbook.

Task 17: Decision-making procedure – This task represents a reflection on the decision-making experiences during the preceding phases in the unit. The purpose of this task is to make the decision-making procedure and the character of its required knowledge input explicit. The students are first asked to construct a model of the decision-making procedure. This is done in a way comparable to task 5 (about constructing a model of the waste issue) by having the students solve a kind of jigsaw puzzle, and write a short story about what the puzzle's solution represents. The puzzle's solution as reproduced in figure 4.11 is roughly identical to the model of a decision-making procedure in figure 3.3. It is expected that students will be able to construct this model of the decision-making procedure by themselves, guided by the puzzle-format of the task. Answering the associated questions about the environmental criteria and the character of issue knowledge established and used throughout the unit in this procedure is not expected to present much of a problem, as illustrated by the full reproduction of the scenario for this task in figure 4.12. These answers prepare for the next task, in which the same kind of questions are asked in the context of other environmental issues.

Task 18: Decision making in other situations – This final task sort of legitimises the students' effort in the preceding task 17 of making the decision-making procedure and the character of its required knowledge input explicit. The purpose of this task is to induce in students the idea that this explicit knowledge about the decision-making procedure is (or could be) useful in other environmental decision-making situations in the areas of water and energy use. This idea is elicited by making the – during the motivation phase (activity 1) already implicitly addressed – analogy between the use

of energy (natural gas and electricity), water and packages explicit: extraction of material from the environment, and addition of waste to the environment. This idea is further strengthened by having the students consider the identified personal environmental decision-making situations from the motivation phase in the unit by answering the same questions featuring in task 17 about the relevant environmental criteria and the related issue knowledge necessary for thoughtful decision making. The answers to this last question provide general questions for further investigation in follow-up series of lessons about decision making on the water and energy issues.

Activity 5

Conclusion

17 Decision-making procedure

During the foregoing lessons you have made a choice between packaging alternatives. In doing so, you have followed a *decision-making procedure*. In this task you are going to visualise that procedure in a scheme by solving a puzzle.
Figure 11 already gives part of the solution. Take the worksheet with the remainder of the puzzle's pieces. Cut out those pieces.

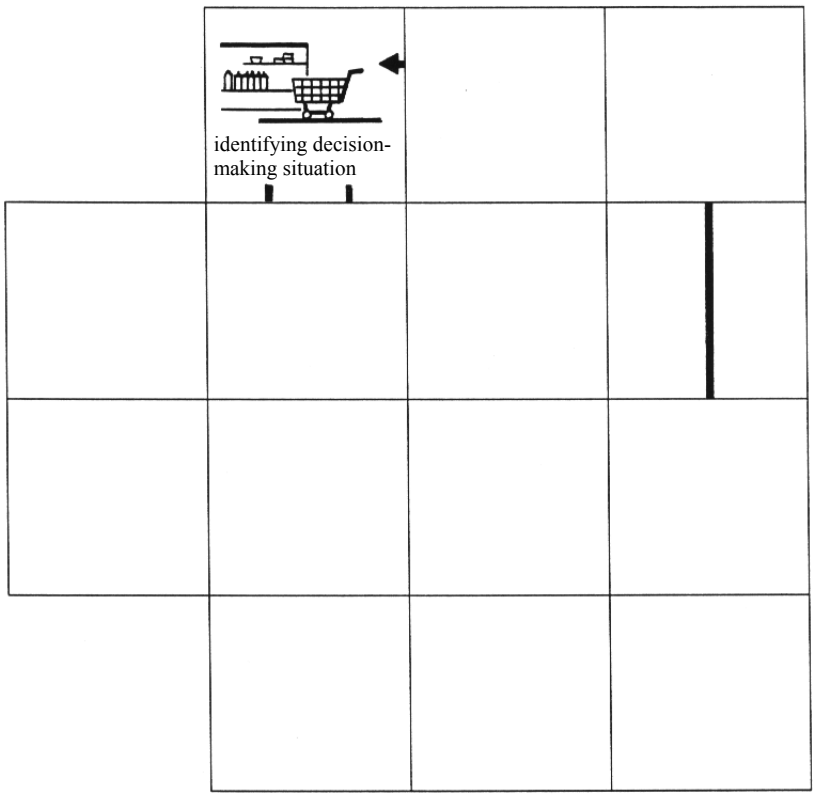


Figure 11 – Scheme of the decision-making procedure.

- Complete the puzzle in figure 11 by fitting in the remainder of the puzzle's pieces. When all pieces are in the right place, fasten them with some glue.
- On a separate sheet write a story about the puzzle's solution: explain what the scheme shows.

Now – after completing the puzzle – answer the following two questions about the scheme.

- On which *environmental criteria* did you compare the packaging alternatives in the decision-making procedure?
- Which *kind of knowledge* did you need for being able to compare the packaging alternatives on those environmental criteria?

18 Decision-making in other situations

In task 17 you have visualised a decision-making procedure about packages. This procedure is (maybe) fit for use in other decision-making situations. Because in activity 1 you have seen that there is a similarity in the use of energy, water and packages at home. This similarity is once again displayed in figure 12.

Figure 12 – The use of energy, water and packages at home. Energy and water do come from somewhere, just like packages do. They are raw materials that man extracts from the environment. And using energy and water does produce waste, just like packages do. Waste that finally is added to the environment.

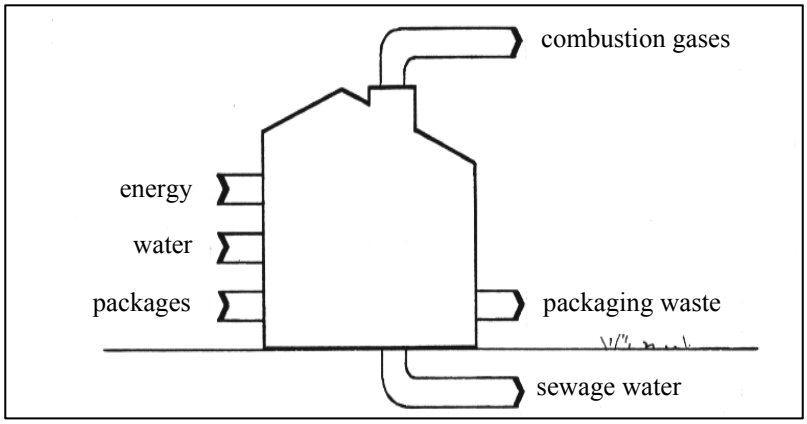


Figure 13 shows three decision-making situations that have to do with the use of energy and water. Choose one of those situations. Answer the following three questions for the decision-making situation you have chosen.

- What are the two *alternatives* in this decision-making situation?
- On which *environmental criteria* do you have to compare those alternatives in the decision-making procedure?
- Which *kind of knowledge* do you need in order to be able to compare the alternatives on those environmental criteria?

---

1 You wish to wash yourself. Do you take a bath or a shower?
2 The filament bulb above your desk has broken down. Do you replace it by a new filament bulb or an energy saving lamp?
3 You have to buy a new pocket calculator. The same calculator exists in two kinds: one is powered by a battery and the other by a solar cell. Which calculator do you buy?

Figure 13 – Decision-making situations.

Figure 4.10 – Student material: the tasks of the reflection phase of the teaching/learning unit. The students' worksheet with the remainder of the puzzle's pieces has been left out. The puzzle's solution is reproduced in figure 4.11.

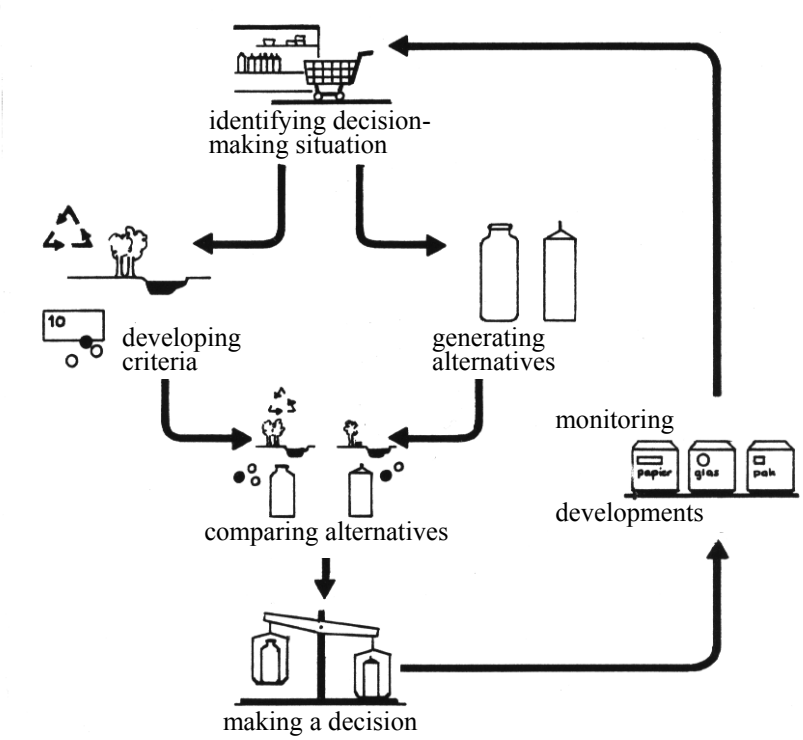


Figure 4.11 – Student material: the students' solution of the puzzle in task 17, representing the model of the decision-making procedure.

Task 17	**Decision-making procedure**
Purpose	• Constructing a model of the decision-making procedure by solving a puzzle on the basis of the students' experiences throughout the unit, and establishing the kind of knowledge necessary for using this procedure successfully.
Introduction	• In this series of lessons we have taken a number of steps in order to arrive at an argued point of view. In a somewhat more difficult wording this means that we have followed a *decision-making procedure*. We are now going to visualise that procedure in a scheme, in order to become fully aware of what those steps are – because maybe that might be useful for tackling those other environmental decision-making situations about water and energy. In this task you are again going to visualise the decision-making procedure by solving a puzzle (comparable to the one in task 5 about what we already knew about packages). And again you write a short (one-page) story about what the scheme is showing. While solving the puzzle and writing the story, think about what you have done so far during the whole series of lessons.
Working method	• Small-group work, followed by whole-class discussion (transparency of puzzle's solution on overhead projector).
Teaching aids	• Overhead projector/transparency (puzzle structure with cut pieces).
Results	• The students have no difficulty in solving the puzzle and writing the accompanying story after the preceding tasks. Constructing and elucidating the puzzle's solution with the help of a transparency on the overhead projector by the teacher is nothing more than offering the students a

	possibility for checking their ideas. The students' questions about or comments on the scheme, if present, should be put to the class for answers and further comments. • The questions about the environmental criteria and the kind of knowledge necessary for comparing packaging alternatives on those criteria are also expected to present not much of a problem: depletion of raw materials (for packaging materials) and pollution through dumping/burning (of packaging waste) will be identified as the environmental criteria, with knowledge about the properties regarding renewability and supply of raw materials, harmfulness in the case of dumping/burning, and recyclability of (packaging) materials as a requirement for being able to make comparisons – so: knowledge about how the (packaging) materials 'score' on the two environmental criteria.
Conclusion	• [As much as possible to be adapted to what has been put forward by the students during the whole-class discussion] So now we know the decision-making procedure for arriving at an argued point of view. And we know what kind of knowledge is needed for using that procedure: knowledge about the environmental criteria, and knowledge about the criteria-related properties of (packaging) materials. Now, in the final task 18, let's see if this knowledge also seems to be fit for use in other environmental decision-making situations …
Time	• 25'

Figure 4.12 – Scenario: the hypothetical teaching/learning process throughout task 17 of the reflection phase in the unit.

The teaching/learning process along the lines of the scenario in the last three phases of the didactical structure is expected to take roughly seven classroom periods of 45 minutes each. Probably four out of these seven classroom periods will have to be spent on the investigation phase in the unit.

4.7 Preview

The outline and examples of the scenario and the detailed tasks in the students' workbook presented in this chapter are the product of curriculum development in the second cycle of developmental research – a product to be put to the test. However, answering questions such as what did happen during the classroom trial of this product during the second cycle of developmental research and what is the empirical support for the underlying didactical structure to be considered 'good enough' for practical purposes (and, if not, what modifications might be necessary) will be postponed for a while. The reason for this is that the teaching/learning unit as described in this chapter has originated not only from the ideas presented in chapter 3, but also from the experiences during the first cycle of developmental research.

The following chapter therefore will deal with the product 'in the making': the *process* of designing, testing and evaluating the unit during the first cycle of developmental research. In describing this process, the focus is on the assumptions about the students' existing issue knowledge and decision-making skill, on the major

design errors in the structure of the teaching/learning process – already hinted at a couple of times throughout this chapter 4 for the sake of raising curiosity – and the necessary modifications, and on an appropriate preparation of the trial teacher. In other words, the following chapter will deal with *reusing* and *recycling* ideas and experiences from the first cycle of developmental research as far as relevant for arriving at the improved second version of the unit and at the desired conditions for its classroom trial.

5 The process: the teaching/learning unit in the making – recycling and reusing ...

5.1 Introduction

Converting a didactical structure into a teaching/learning unit almost inevitably takes more than one cycle of developmental research. During the first cycle the design of the tasks and the assumptions about the outcomes of these tasks could not be based on earlier experiences, so one had to rely on 'educated guesses' – educated in the sense of what reasonably or logically might be expected, given the structure and sequence of the tasks, given the ideas about the students' pre-knowledge and decision-making skill, and given an adequate teacher preparation. In the evaluation of the classroom trial of the unit's first version a comparison between the expected and the actual outcomes has resulted in ideas about the modifications to be made in the structure and sequence of the tasks and in more grounded assumptions about the outcomes of the modified tasks – of course, as far as the identified deviations from the scenario in classroom practice could be understood. The purpose of this chapter is to provide some insight into the results of the classroom trial of the unit's first version regarding the assumptions about the students' existing motive, issue knowledge and decision-making skill, the major design errors, the teacher's teaching style, and the resulting ideas about necessary modifications and an appropriate preparation of the trial teacher – thus paving the way for the second cycle of developmental research.

This chapter in section 5.2 first briefly specifies the research design during the first cycle of developmental research. The evaluation of the classroom trial during this cycle shows a mix of positive and negative results. To start on a positive note: the assumptions about the students' existing motive, pre-knowledge and decision-making skill as described in chapter 3 (sections 3.3 and 3.4) were largely confirmed during the classroom trial of the unit's first version, as is dealt with in section 5.3. The negative results did concern the identification of some structural design errors in the unit's first version. The identified major design errors and the modifications thought necessary for arriving at the improved second version of the unit as described in chapter 4 are discussed in section 5.4. Finally, the classroom trial also revealed some problematic aspects of the trial teacher's didactical approach while teaching the unit. The emerging ideas about what might constitute an adequate teacher preparation for the classroom trial of the revised unit in the second cycle of developmental research are presented in section 5.5. The concluding section 5.6 reflects on the process of developmental research so far. It focuses on the interaction between the ideas about the students' pre-knowledge and skill and about the desired

character and structure of the teaching/learning process as set out in chapter 3. It also deals with the practice of actually writing the unit, as well as with preparing for, observing and reflecting on its classroom trial.

5.2 Research design

In chapter 3 the research design has been sketched in rather broad lines (section 3.5). For the first cycle of developmental research this design will be described below in some more detail. A similar, more extensive description for the second cycle will be given in chapter 6, which will also address a number of methodological aspects.

During the first cycle of developmental research a first version of the teaching/ learning unit (a scenario and student materials) for decision making about the waste issue was developed on the basis of the – at that time still developing – ideas presented in chapter 3. The main features of this unit were a first attempt at productively using the students' assumed existing motive, issue knowledge and decision-making skill (section 3.3) and an emerging five-phase problem-posing teaching/ learning process of motivation, question, investigation, application and reflection (section 3.4) (Kortland, 1996b). The student tasks in each of the five phases were, of course, at some instances slightly and at other instances considerably different from the unit's second version described in chapter 4.

The first version of the unit was tested during the school year 1995-96 in one grade 9 class with 30 middle-ability students (18 female and 12 male). These students were used to the traditional mode of teacher-centred whole-class teaching, as this was (up till then) the predominant teaching mode at the trial school. The class was taught by one of the trial teachers who also had been participating in the earlier phase of exploratory research and development concerning the NME-VO project's garbage unit as described in chapter 2.

The trial was prepared by thoroughly discussing the teaching/learning unit in all its aspects – guided by the scenario – and turning the results of these discussions into a detailed, schematic planning of each lesson. During the trial all lessons were observed and audio/video-taped. The transcripts of these tapes have been used to answer the question whether or not the unit seemed to be 'good enough'. That is, whether it sufficiently achieved what is was supposed to achieve. The answer would then serve as an input into the second cycle of developmental research.

5.3 Motive, issue knowledge and decision-making skill

To what extent were the assumptions about the students' existing motive, pre-knowledge and decision-making skill confirmed during the classroom trial of the unit's first version? This question is answered below by briefly describing the

relevant tasks and the outcomes of these tasks as observed during the classroom trial.

Motive

The motivation phase of the teaching/learning process started with offering the students a limited amount of audio-visual information about the processing of household waste, after which they were asked why their 'learning more about the waste issue might be useful'. It was expected that the students themselves would indicate the decision-making situations in which (more) knowledge about (packaging) waste might be useful, because the audio-visual information hinted at a citizen's responsibility for waste prevention and waste separation for recycling purposes, and at the possibility of taking up this responsibility through shopping and waste disposal behaviour.

In the classroom trial this first lesson started in a quite positive atmosphere. The students were not reacting to the topic in a negative way – also not overtly enthusiastic, but 'not negative' is already quite something with such a somewhat grubby topic. After watching the video, the students answered the question of 'why learning more about the waste issue might be useful' as reproduced in figure 5.1. As far as the waste issue is concerned, these students seemed to point at aspects of amount of and pollution by dumping and burning waste – both considered by them as being 'a problem'. And as far as solutions to this issue are concerned, these students pointed at their own 'buying and waste disposal behaviour' – in line with the scenario's expectations.

S_1 Then you know what kind of packaging material you dispose of.
S_2 You learn to better separate waste, and that is less detrimental to the environment.
S_3 You will do your shopping more consciously.
S_4 The problem is getting bigger and bigger, because people want more and more.

Figure 5.1 – Whole-class discussion: students' reactions to the question of why learning more about waste might be useful.

According to the students – though rephrased – learning more about packages could be useful with a view to 'better dealing with household waste and waste separation' and 'better paying attention when buying packed products'. This would mean that the students did recognise their potential 'to contribute to a better environment' through thoughtful decision making about packages, and implicitly by using words like 'better' (S_2) and 'more' (S_3) did indicate a certain willingness to do so – or at least to *learn* to do so. This could be seen as a confirmation of the assumption about the students' existing motive in terms of a willingness to contribute to 'a better environment' as stated in chapter 3 (section 3.4).

Issue knowledge

The question phase in the teaching/learning process started with a number of tasks in

which the students' everyday life experiences with buying packed products and disposing of empty packages did act as a starting point for eliciting and structuring their shared pre-knowledge about household packaging waste through a process of alternating periods of small-group work and whole-class discussion. These tasks roughly concerned answering questions about the way of processing each one of a carefully selected collection of empty packages. A portion of the packages in the collection was included with the intention of raising questions about their waste-related properties, either through students disagreeing about their individual pre-knowledge or through simply not knowing – questions that could be transformed into questions for further investigation. Finally, near the end of this question phase the students were asked to reflect on the outcomes of the preceding tasks by summarising their questions for further investigation and by constructing a model of the waste issue out of their 'bits and pieces' of waste issue knowledge through solving a puzzle and writing a short story about what the puzzle's solution represents – roughly the same task as task 5 described in chapter 4 (section 4.3).

In the classroom trial the assumptions about the students' existing general issue knowledge and incomplete specific issue knowledge as stated in chapter 3 (section 3.3) as well as their ability to construct a model of the waste issue (in a puzzle format) were shown to be largely correct. Their existing general issue knowledge was either directly put forward or could be summoned by the teacher's careful questioning in a relatively easy way. The construction of the model of the waste issue then did not present much of a problem. The questions for further investigation, although identified and summarised in a far too much teacher-directed way, reflected the expected need for extending the students' specific issue knowledge in terms of waste-related properties of packages and packaging materials.

Decision-making skill

Near the end of the question phase the students were introduced to a decision-making situation about milk packaging: carton or bottle. They were asked to make a decision, to reflect on the point(s) on which they compared the packaging alternatives, to list the other points on which they thought the alternatives could be compared and to compare the alternatives on each point separately. This task related to the students' existing decision-making skill as identified in chapter 3 (section 3.3): comparing alternatives on one or more self-chosen criteria. It was expected that individually (each group of) students would come up with only one or two, but collectively would mention a large number of points (or: criteria) for comparing (or: evaluating) the packaging alternatives. Throughout the remainder of the unit in the investigation and application phases a portion of the student tasks then focused on identifying the environmental criteria and tackling decision-making situations about packages using these criteria (and, of course, their extended issue knowledge from the investigation phase). In the final task of the application phase the students were asked to reflect on their decision-making experiences by constructing a model of the decision-making procedure through solving a puzzle and writing a short story about what the puzzle's solution represents – roughly the same task as task 17 described in

chapter 4 (section 4.6), but without the associated questions about the environmental criteria and the character of the necessary issue knowledge.

In the classroom trial it appeared that students experienced the first decision-making task as difficult. Furthermore, this task was dealt with in an unsatisfactory way. The teacher appeared to be a bit stressed, as the foregoing tasks about eliciting and structuring the students' shared pre-knowledge about household packaging waste had already taken up far more teaching time than was expected and planned. The whole-class discussion therefore turned out to be limited to some of the students putting forward their argument(s). Making the character of those arguments explicit (a comparison between the two alternatives on a criterion) and identifying the criteria used was just being left out. However, an analysis of the students' performance on this task in their workbooks showed that they either implicitly or explicitly compared the alternatives on one or more criteria, and were able to correctly identify this criterion. This could be seen as an indication that the assumption about the students' existing decision-making skill was largely correct. It must be noted, however, that this roughly concerned only half of the students. That is, those students that had been able to give a more or less complete answer to the task's questions – an indication of the difficulty of this task as perceived by the students.

At a later stage, the task of constructing the model of the decision-making procedure did not seem to present too much problems, except for the interpretation of the step of 'monitoring new developments'. According to the scenario this step should have been addressed as a part of the foregoing decision-making exercises, but did not get any attention in classroom practice.

5.4 Structural design errors

The classroom trial of the unit's first version did provide an indication that the assumptions about the students' motive, issue knowledge and decision-making skill were largely correct. This finding, however, is based on what happened in classroom practice concerning a number of 'isolated' tasks. It does not say anything about the adequacy of the character and sequence of the tasks as building blocks of an internally consistent teaching/learning process. To what extent could the structure and sequence of the tasks in the unit's first version be considered adequate in this respect? This question is answered below by briefly describing the *major design errors* in the unit's first version, resulting from a reflection on the outcomes of its classroom trial. These design errors do not concern the sequence of the five phases of the teaching/learning process as outlined in chapter 3 (section 3.4), but relate to the character and sequence of the tasks in each of these five phases.

Motivation phase

Given the purpose of the motivation phase, the question to be answered in a reflection on the outcomes of the classroom trial is: were the students provided with a

motive for starting their learning about packaging waste, and did they get a first idea that this learning is aimed at becoming able to take 'a better environment' into account in decision-making situations concerning packaging alternatives?

Design errors – The answer to this question was a clear *no*. The tasks in the motivation phase did not give a sufficiently clear idea of the unit's intention: (learning) to make a thoughtful, argued choice between packaging alternatives in order to be(come) able to contribute to 'a better environment' – if one should want to do so. What seemed to be the case was that students did indeed make a connection between 'a better environment' and their buying and disposal behaviour – as already outlined in the preceding section. However, this connection was not used productively to clearly define the decision-making situations the unit was going to deal with. Furthermore, the students were not given a preview on their learning process by linking 'learning about packaging waste' to the context of decision making about packages.

The lack of attention paid to clarifying the students' prospective learning process had its repercussions later on in the unit, at the start of the application phase in which the students were expected to apply their extended issue knowledge to packaging decision-making situations. After having found answers to their questions about packaging waste in the preceding investigation phase, the strong impression was that students thought the unit had been finished: now we know all there is to know about packaging waste, so that's it. Furthermore, the students seemed to be a bit reluctant to continue with the unit at this stage. This means that it was not very clear to them *why* they had been learning about packaging waste. The decision-making situations as put forward by themselves in the motivation phase were not seen by them as situations in which applying their extended knowledge about packaging waste would be of help in reaching an argued decision.

Including – or at least strengthening – the decision-making context in the motivation phase of the unit's second version would have been a relatively easy task. However, the tasks in the unit's first version had other, and less easy to solve deficiencies. In the whole-class discussion the teacher as well as the students indicated household waste as being a problem. But the character of this problem remained rather unclear – and seemed to remain unclear throughout the rest of the unit as will become apparent when dealing with some of the other phases. The vague notion of contributing to 'a better environment' thus also remained vague. A second point of concern did relate to the students' motive for starting to study the topic. Right from the start the unit was dealing with packaging waste, and was trying to focus on the students' action perspective in this respect. But contributing to 'a better environment' through choosing between packaging alternatives might seem a bit 'shallow' to students, in the sense that such a contribution would not have very much impact. This perceived insignificance of their action perspective might be detrimental to the students' motive to learn more about the waste issue and to apply their extended knowledge in decision-making situations.

Modification – The modification of the tasks constituting the motivation phase should address the above mentioned design errors: the modified tasks should – in one way or another – clearly define the decision-making situations as the context of the students' learning process, should pay some attention to what 'a better environment' is, and should counter the idea of contributing to 'a better environment' through decision making about packages as being just peanuts. These considerations have led to the modified design of the motivation phase described in chapter 4 (section 4.2), in which the tasks far more clearly reflect the environmental decision-making context and the exemplary character of decision making about packages in this respect, and in which the tasks also prepare for a necessary definition of what contributing to 'a better environment' exactly is in the next phase of the teaching/ learning process.

Question phase

Given the purpose of the question phase, the question to be answered in a reflection on the outcomes of the classroom trial is: did the students become aware of a need for extending their specific issue knowledge in the light of the global motive, and did they formulate this need in the form of their own questions for further investigation?

Design errors – The answer to this question was: *no, not really*. The classroom trial did confirm the students' assumed pre-knowledge about the waste issue, and the connected questions for further investigation that came forward did indeed express the expected and intended need for extending their specific issue knowledge in terms of knowledge about waste-related properties of packages and packaging materials. However, this becoming aware of a need for extending their knowledge in a specified direction certainly did not take place in the light of the global motive: contributing to 'a better environment' through decision making about packages. The questions for further investigation did turn up as a result of the rather lengthy set of tasks aimed at summoning existing and non-existing knowledge about the waste issue as such, unconnected to decision making – a repetition of the identified design error in the motivation phase. During the (lengthy) whole-class discussions triggered by the tasks, the intended questions (about waste-related properties of packages and packaging materials) for further investigation did emerge. This means that the students did become aware of a need for extending their specific issue knowledge. However, as these questions did emerge only occasionally during the lengthy whole-class discussions taking several lessons, they had to be 'collected' afterwards in a heavily teacher-directed way. It therefore cannot be said that the students did formulate this need for extending their specific issue knowledge in the form of *their own* questions for further investigation. It was the teacher who formulated these questions, making use of what had been put forward by the students. Furthermore, it cannot be said that the students did become aware of a need for extending their specific issue knowledge *in the light of the global motive*. First of all, this global motive of 'contributing to a better environment through choosing between packag-

ing alternatives' was not – or at least insufficiently – induced during the motivation phase. Secondly, in the question phase the questions for further investigation did not emerge in such a decision-making context. Therefore, the students could not be expected to suspect that finding an answer to these questions would enable them to improve on their decision making about packages – let alone the question of whether and in which way their decision making about packages would be in need of improvement at all.

Next to this major design error, the remaining tasks in this phase had other deficiencies. Near the end the decision-making context only appeared as a kind of 'add on' in the form of a decision-making exercise dealing with identifying criteria for comparing packaging alternatives. This task had the purpose of eliciting the question of what the relevant criteria for comparing packaging alternatives could be. At the beginning of the investigation phase, therefore, the environmental criteria for comparing packaging alternatives were not yet established and the question of what contributing to 'a better environment' might be was not explicitly addressed. This sort of blurred the focus of the investigation phase, which in effect dealt with the *criteria-related* properties of packages and packaging materials. After this decision-making intermission the question phase was concluded by constructing a model of the waste issue in a puzzle format, with the only purpose of having the students summarise the whole-class discussions about the results of the preceding tasks. At this point in the unit, therefore, the puzzle's solution was not used productively, for instance, to identify the environmental criteria for comparing packaging alternatives. Although this was going to be done in the application phase, the students could not yet know that at the end of the question phase.

Modification – The modification of the tasks constituting the question phase should address the above mentioned design errors: the modified tasks should establish the environmental criteria for comparing packaging alternatives (e.g., by making a productive use of the students' existing issue knowledge), and should summon the intended questions for further investigation about the *criteria-related* properties of packages and packaging materials in a *decision-making context*. These considerations have led to the modified design of the question phase described in chapter 4 (section 4.3).

In the modified unit the audio-visual information about the waste issue, originally used in the motivation phase, now starts off the question phase as a means of triggering the students' issue knowledge – immediately followed by the next task of having them construct a model of the waste issue in the earlier outlined puzzle format. So, this task of structuring the students' existing issue knowledge has been moved from the end to the beginning of this phase, and at the same time the lengthy – and in classroom practice somewhat boring – set of tasks aimed at summoning the students' existing and non-existing knowledge about the waste issue has been removed. With this shift, the puzzle task gets a distinct purpose other than just summarising: making explicit what is meant by 'a better environment' in terms of less depletion and pollution, by making a productive use of the students' structured

existing issue knowledge. This in turn paves the way for connecting to decision making, with depletion and pollution as environmental criteria. Now the 'add on' decision-making exercise in the unit's first version can be turned into a far more focused task of comparing two packaging alternatives on these environmental criteria, with the purpose of triggering the intended questions for further investigation. Or, in other words: these questions now emerge in the context of *decision making* – so, in the light of the global motive established in the preceding phase of the modified unit.

These modifications in terms of reusing and recycling the original tasks in the unit's first version lead to an increased coherence of the teaching/learning process. At the same time these changes increase the variety in working methods.

Investigation phase

Given the purpose of the investigation phase, the question to be answered in a reflection on the outcomes of the classroom trial is: did the students extend their specific issue knowledge, guided by their questions for further investigation?

Design errors – The answer to this question – it might start getting a bit monotonous – was: *no, probably not*. In order to limit the amount of time required for the intended research, the tasks in the investigation phase reflected a labour-dividing approach: small groups of students each carried out an independent investigation by using written and audio-visual reference materials, by performing experiments and/or by doing fieldwork (interviewing experts) in order to find an answer to one of the questions for further investigation, and shared their findings in a reporting session. From the contents of the reports presented by each group it could be concluded that the students did extend their knowledge about waste-related properties of packages and packaging materials, but only with respect to the property (or question) the group itself had been investigating. The remainder of the specific issue knowledge had to be gathered from the oral presentations of the other groups to the class. The restless classroom atmosphere during the reporting session, combined with the difficulty the groups had with presenting their findings in a clear, structured and understandable way, made the effectiveness of knowledge transfer in this process of 'students learning from each other' questionable. This means that the labour-dividing approach in this phase could be considered another design error, very probably leading only to a *partial* extending of specific issue knowledge, limited to just the part that was investigated by the group itself.

Modification – The modification of the tasks in the investigation phase should address the above mentioned design errors: the tasks should be modified in such a way that each student extends his or her knowledge about *all* waste-related properties of packages and packaging materials, guided by *all* questions for further investigation formulated in the preceding question phase. These considerations have led to the modified design of the investigation phase described in chapter 4 (section 4.4).

The necessary modification is relatively easy: remove the adopted labour-dividing approach, and engage all students in extending their specific issue knowledge across the complete set of questions for further investigation – no longer relying on the students' still rather weak presentation skill. Moreover, the modifications in the preceding phases now make it possible to structure the extended knowledge with the help of the two established environmental criteria into a format suitable for immediate use in decision making during the application phase. The reporting session, which is still considered a useful preparation for the use of this working method in one of the tasks in the application phase, is now connected to the additional and less crucial task of experimenting and interviewing at the end of the investigation phase.

Application phase

Given the purpose of the application phase, the question to be answered in a reflection on the outcomes of the classroom trial is: did the students use their extended knowledge for the purpose it has been extended for – that is, for arriving at an argued point of view in the decision-making situations which did provide a motive for starting and continuing their learning process?

Design errors – The answer to this question – for a change – was: *yes, to quite some extent*. However, due to the identified design errors in the preceding phases of the teaching/learning process it is questionable whether the students when using their extended knowledge realised that they were using it for the purpose it had been extended for.

The first task in this phase again represented a design error. The students were asked to reflect on their model of the waste issue constructed earlier, with the aim of identifying the environmental criteria for comparing packaging alternatives. Due to the persisting lack of clarity about what contributing to 'a better environment' might be, this task resulted in a wealth of criteria relating to depletion of raw materials (or: renewability), pollution through dumping and burning, necessity and reusability of the package, and recyclability of the packaging material. This long list of environmental criteria made the consecutive decision making in the next task hard to tackle. This next task was roughly the same as task 13 about the carton/bottle decision-making situation in the unit's second version as described in chapter 4 (section 4.5). In this decision-making situation the students were using their extended specific issue knowledge in a satisfactory way in comparing the packaging alternatives on the established environmental criteria. The whole-class discussion resulted in roughly correct and complete comparisons of the alternatives on each of the criteria, and concluded with a weighting of the comparisons made. However, as already mentioned, the list of criteria established in the preceding task was quite long, thus making the review of comparisons in order to reach a decision somewhat complicated.

After this first experience in applying their extended specific issue knowledge to decision making things start to go off-track. The purpose of the next tasks was to

have students arrive at the formulation of the requirements an argued point of view should meet. First the students were asked to criticise a limited number of given argumentations in the now familiar carton/bottle decision-making situation. These argumentations were deficient in comparison to their decision making in the foregoing task: alternatives were compared on only one criterion, only one alternative was addressed (so: no comparison), and information about one or both alternatives was incomplete and/or incorrect. Part of this task is reproduced in figure 5.2, with only one example of a poorly argued point of view given. It was assumed that the students would be able to detect these deficiencies by comparing the given argumentations to their own decision making in the preceding task. Criticising the given argumentations was expected to prepare the students for the next task, also reproduced in figure 5.2. In this task students were asked to formulate the requirements an argued point of view should meet. It was thought that the students in a whole-class discussion would agree upon something like the following requirements: a correct comparison of both alternatives on each of a complete range of relevant and clear criteria, concluded by an overall weighting of the separate comparisons on the criteria used.

27 Criticising argumentations

In task 26 you gave an argued point of view in the bottle/carton decision-making situation. And therefore you will be able to say something about the argued point of view of others.
Below you find four argued points of view in the bottle/carton decision-making situation. For each argued point of view, write down what you think is *well* and *not so well* about the *argumentation*, and why. In doing that, keep in mind what you have been doing yourself in task 26. And watch this: it is not important whether or not you agree with the *choice* made. The important thing is your judgement of the given *argumentation*.

- Point of view:
  I choose the milk carton, because that is good for the environment. The carton is recyclable: it can be turned into recycled writing paper. Also, cartons are not so heavy and are easier to handle in pouring the milk.

[...]

28 An argued point of view

In task 27 you have criticised a few argumentations. From your criticisms you can derive which requirements a well-argued point of view should meet.

- Which requirements should a well-argued point of view meet? Or, in other words: which elements does such an argumentation contain, and in which order? Illustrate each requirement with an example from task 27: an example that meets or does not meet this requirement.
- Why is being able to present a well-argued point of view important?

Figure 5.2 – Student material: reflecting on decision making by others and formulating requirements an argued point of view should meet.

Both tasks proved to be extremely difficult for the students. The small-group work on these tasks resulted in mostly blanks, a further explanation by the teacher of the

intention of these tasks did not appear to be very fruitful in this respect, and in the whole-class discussion the students came up with examples of the given argumentations being incorrect concerning waste-related properties of packages and packaging materials exclusively. The logical requirement an argued point of view should meet then was – according to the students – that 'it should comply with the facts', that the waste-related properties (the 'facts') mentioned in the argumentation 'should be correct'. The inclusion of these tasks could be considered as another design error. Both tasks were not aimed at having students use their extended specific issue knowledge in decision-making situations, but at reflecting on decision making itself. A reflection aimed at making explicit the general characteristics of its expected product: an argued point of view.

The application phase was concluded with constructing a model of the decision-making procedure in a puzzle format, with the purpose of providing the students with a tool for tackling a self-chosen decision-making situation in the reflection phase. Although this task was also aimed at decision making itself, the students appeared to have less difficulty with performing this task. This seemingly contradictory result might be explained by the puzzle format, which made the task more 'down to earth' for students of this age and ability level. But in addition – and probably of more importance – this task offered the students the possibility to return and to refer to their own experiences in coping with the carton/bottle decision-making situation, as was apparent in their written stories about what the puzzle's solution is showing.

Modification – The modification of the tasks in the application phase should address the above mentioned design problems: the modified tasks should concentrate on having the students use their extended knowledge in decision-making situations about packages. That is, the kind of situations their knowledge has been extended for. These considerations have led to the modified design of the application phase described in chapter 4 (section 4.5).

The first task in the modified application phase could be left roughly unchanged: the students were quite able to cope with the bottle/carton decision-making situation in a satisfactory way. As a result of earlier modifications, this task would be even easier to cope with, as the environmental criteria for comparing the packaging alternatives have already been established – and limited to the essential two – in the modified question phase. This could then be followed directly by asking students to do their decision making in a self-chosen situation of a comparable nature: a shift of one of the tasks in the reflection phase to the modified application phase. Reporting about this decision making could then be aimed at identifying the requirements an argued point of view should meet, by reflecting on what the students themselves have been putting forward instead of by reflecting on a number of constructed and artificial anonymous argumentations.

A quite different problem was the students' reluctance to start working on the tasks in the application phase during the classroom trial of the unit's first version. It might be expected that the modifications made in the foregoing three phases,

including the teacher's efforts at making the teaching/learning process explicit at a number of suitable instances, would be enough for showing the students what the purpose of extending their knowledge is, so that applying this extended knowledge in decision-making situations 'does not come as a surprise to them' anymore.

Reflection phase
The purpose of the tasks in the reflection phase is to have students reflect on the character of their extended knowledge and of the decision-making situations in which this extended knowledge could be useful – as stated in chapter 3 (section 3.4). However, at the time of designing the tasks in the unit's first version this purpose was not yet very articulated. The above expressed purpose of this phase has more or less emerged during the evaluation of the classroom trial of the unit's first version.

Design errors – In the final task of the unit students were asked to formulate an argued point of view in a self-chosen decision-making situation about packages, without any guidance except for some general references to the decision-making procedure (the puzzle's solution from the preceding task in the application phase) and to the reference materials about packages and packaging materials used in the investigation phase. During another presentation session they were expected to use the earlier identified requirements an argued point of view should meet and their extended issue knowledge for assessing the quality of their fellow students' argued points of view. Given the in the application phase observed difficulty and resulting impossibility of identifying the requirements an argued point of view should meet, this task obviously did represent a (final) design error. The decision making itself would be possible, but a reflection on the quality of the decision-making products (the argued points of view) would be asking too much of the students.

Modification – The necessary modification of the tasks in the reflection phase has already partly been suggested: moving the decision-making task to the application phase. The modified reflection phase could then start with making explicit the decision-making procedure as experienced by the students throughout the unit. This means moving the construction of a model of the decision-making procedure in a puzzle format from the application phase to the reflection phase. However, the purpose of this task then has to be clearly tuned to the modifications in the preceding phases. These considerations have led to the modified design of the reflection phase described in chapter 4 (section 4.6) – a design that meets its retrospectively formulated purpose of having the students reflect on the character of their extended knowledge and of the decision-making situations in which this extended knowledge could be useful.

Structural design errors
The evaluation of the classroom trial of the unit's first version did reveal a number of design errors concerning the student tasks in each of the five phases of the didactical structure. In summary, the major design errors did concern the *global motive*,

the relationship between *issue knowledge and decision making*, and the *reflection on decision making*.

Global motive – The motivation and question phases of the unit did not clearly enough communicate the overall intention of the teaching/learning process: (learning) to make a thoughtful, argued choice between packaging alternatives in order to be(come) able to contribute to 'a better environment' – if one should want to do so. Neither the decision-making context, nor the relevant environmental criteria for decision making about packages became clear. Therefore, it could not become clear that there would be something to learn in this respect, what there would be to learn, and how this learning would be going to take place in the oncoming lessons.

Issue knowledge and decision-making – In the question phase of the unit the effort of eliciting and structuring the students' existing and not-yet-existing issue knowledge was not – or at least not enough – linked to decision making about packages. The connection with the (already rather weak) global motive was therefore lacking. Moreover, the formulated questions for further investigation and the research guided by these questions initially had no clear relevance for the students. Furthermore, the questions for further investigation were formulated in a process in which it was rather the teacher who reconstructed and classified the students' collection of questions. Therefore, these questions were more likely to represent teacher questions that by hook or by crook have been related to the questions the students had been putting forward. The crucial connection between the students' own questions for further investigation and the questions-guided research was too weak.

Only near the end of the teaching/learning process in the application phase the connection between the extended issue knowledge and decision making about packages became stronger, but still stayed implicit. Moreover, at that later stage the environmental criteria were still not yet clearly defined, which made the decision making unnecessary complex and confusing.

Reflection on decision making – In the application phase of the unit the question which requirements an argued point of view should meet was not clearly enough related to the *presentation* of an such an argued point of view, and answering this question could not be based on sufficient decision-making experiences by the students. Finally, the task of making explicit the decision-making procedure was inappropriately situated in the application phase of the unit, as it does represent a *reflection* on the students' experiences with decision making about packages in the unit so far. Moreover, the purpose of this task was unclear, as the activity was not presented in the context of decision making about other environmental issues in which the procedure might be a useful general tool.

These major design errors in the unit's first version reflect a teaching/learning process with too little coherence. The design lacked coherence right from the start and throughout the teaching/learning process, as the overall intention of the unit

remained vague, the connection between the consecutive phases of the unit was rather weak, and the purpose of their constituting tasks as well as their interrelatedness was not always clear. Therefore, the conversion of the didactical structure into a teaching/learning unit during the first cycle of developmental research could be said to have resulted in some *structural* design errors. Of course, this lack of coherence in the design has had its repercussions on the fluency and clarity of the teaching/learning process as perceived by the students.

5.5 Teaching style

The classroom trial of the unit's first version did not only reveal the structural design errors identified in the preceding section, but also quite another kind of problem: *teaching style* in combination with a frequent use of *whole-class discussions* prepared by small-group work. Whole-class discussions draw heavily on the teacher's skill of correctly interpreting and connecting to what is being put forward by the students, and of guiding the course of their learning process. Furthermore, an important but unfamiliar task of the teacher is continuously taking care of an explicit *transition* from one task to the next, and occasionally stimulating an explicit *retrospection* on what has happened so far and providing a *preview* of what will happen in the remainder of the series of lessons – thus helping the students to see the logic and consistency of their learning process. Needless to say that the structural errors in the design of the teaching/learning process did not make this task any easier for the trial teacher.

The evaluation of the classroom trial of the unit's first version showed that at times the teacher had considerable difficulties in adequately performing these tasks. This, of course, raised a question about the adequacy of the way in which this classroom trial was prepared in co-operation with the teacher. So, what exactly went wrong? What did the preparation of the teacher on the classroom trial of the unit's first version consist of? And what might be a more adequate teacher preparation? The answers to these questions will be briefly explored below.

Whole-class discussions

In preparing the classroom trial of the unit's first version with the teacher quite a lot of time was spent on going through the scenario, concentrating on the expectations of what students would bring forward as a result of their small-group work on the tasks and concentrating on the line of questioning to be taken by the teacher – if necessary – to arrive at the described, intended outcomes of the tasks. However, putting this into practice was something else completely.

The first problem for the teacher was to give up his traditional role of instructor for most of the time. Quite often the teacher succeeded in doing so, an example being the way he guided a large part of the whole-class discussion of figure 5.3. But there were also times when he could not suppress his instinct of 'telling the right

thing', an example being the first part of the whole-class discussion of figure 5.4 in which the students' differing pre-knowledge about how to dispose of an empty milk carton is settled by the teacher – in a for the student (S_2) unsatisfactory way.

The second problem for the teacher was to avoid posing suggestive questions and giving hasty interpretations of what students were putting forward. An example of this can be found in the last part of the whole-class discussion of figure 5.3, where the teacher gives an interpretation of what the student was saying about the time it takes for trees to grow up. The only thing the student had to do is to confirm this interpretation, which she would readily do as this interpretation coming from the teacher could be considered as having some authority. What the student herself was thinking remains in the dark. Posing suggestive questions and giving hasty interpretations seemed to be triggered by the described, intended outcomes of the tasks in the scenario. Especially if the teacher had the feeling that the whole-class discussion was taking too long, either for the students or for himself with a view to the time schedule, these descriptions in the scenario easily prompted the teacher to suggest 'the right answer' or to interpret the students' utterances – without really checking those carefully – in the direction pointed at by the scenario. Such a result-oriented role of the teacher in whole-class discussions certainly got problematic where it concerned key features of the unit, such as to have the students formulate their own questions for further investigation in the question phase. An example is the final part of the whole-class discussion in figure 5.3, where the teacher formulates such a question on the basis of his own interpretation of what the student had been putting forward. In this case the intended question did indeed emerge, but not at all in the way it was intended to emerge according to the scenario. Therefore it is very doubtful whether this question really represented a students' *own* question for further investigation that should drive their learning process in the investigation phase.

T Now why do we do that with this waste […], such as paper and glass? Why do we collect that separately?
S_1 You cannot recover that from the waste.
T You mean: when it goes to the incinerator?
S_1 Yes.
T But then why do we collect it separately beforehand?
S_1 Well, that's cheaper.
T Why is that cheaper? Could you explain that?
S_1 [unintelligible]
T Which materials does it consist of, paper? What kind of substance is that? How do we get that?
S_1 By cutting down trees.
T Cutting down trees. And if you cut down trees, you can make paper out of that amongst other things. So, what's the advantage?
S_2 You save trees.
T Yes, you have to cut down less trees. [...] So, this waste […]: we collect it separately and reuse/recycle it because then we save raw materials ... trees. [...] Then we have to cut down fewer trees. Is that a problem, cutting down trees?
S^s Yes/It's a pity/No, they are being sowed again, isn't it?
T No problem, you say, because trees are being sowed again and will grow up. So, no problem?

S^s Yes/But that takes an awful lot of time/We get oxygen from them, isn't it?
T What about oxygen? Could you explain that?
S_3 Trees give off oxygen, yes.
T Then we have less oxygen. Still other reasons? ... If these trees grow up again, then why is that a problem? Why bother about all that waste paper? Why don't we just simply burn it?
S_4 But it takes quite a long time before those trees have grown up.
T Yes. So probably you're afraid that those trees are being cut down more quickly compared to the time it takes them to grow up.
S_4 Yes.
T So the question is: could they run out – in future.

Figure 5.3 – Whole-class discussion: an example of the teacher adequately guiding the whole-class discussion by asking for further clarification of the students' utterances, but near the end shifting towards interpreting these utterances in order to arrive at the result 'prescribed' by the scenario.

T Ok, the next one: a milk carton.
S^s Garbage bag/Old newspapers/In waste paper box.
S_1 Garbage bag.
S_2 No.
S_1 Sure yes, there's plastic in it.
T She says: there's plastic in it – on the inside. Could it then go into the waste paper box?
S^s No.
T Do you [S_2] agree with her [S_1]?
S_2 Yes.
T So it has to go into the garbage bag. Does everyone agree? No other opinions?
S_2 I guess so [inaudible for T, unconvinced].

[…]

T An empty bottle of correction fluid.
S^s Chemical waste.
T Household chemical waste. Does someone throw that in the garbage bag?
S_3 Yes, garbage bag.
T Well, so there we disagree. No problem. We'll write it down [on the blackboard]: correction fluid in garbage bag or with chemical waste?

[…]

T You see we agree about a lot of things. There are a couple of things we disagree about. And it is just the intention that we disagree. In a moment we are going to write that down in task 8. That we call research questions. A research question means that you are going to search for an answer, with the help of books, of an experiment – that can be anything, also an expert. This is something we will encounter more often: things we disagree about – and it's quite good that we find those.

Figure 5.4 – Whole-class discussion: an example of the teacher reacting to the students' differing pre-knowledge in a non-appropriate and in an appropriate way, respectively.

Explicit teaching/learning process

Another problematic aspect of the classroom trial was the teacher's way of dealing with making a transition between the successive tasks. In most cases it appeared that the tasks were treated as being unconnected to each other. Or, in other words: the

teacher did not sufficiently use the results of what had been put forward by the students during one task for making a transition to clarifying the next task's purpose. This means that the *local* teaching/learning process was not being made explicit, and that it was left to the students themselves to 'discover' the logic and consistency – if present – of why they were doing what.

A comparable problem turned up concerning the *global* teaching/learning process: looking back at what has been done so far, and looking forward to what thus still has to be done was lacking most of the time – the example of looking forward to what the students are expected to do with the questions for further investigation in the whole-class discussion of figure 5.4 was one of the few exceptions to this 'rule'. However, the same whole-class discussion fragment also illustrates that those few instances of looking backward and forward almost invariably were completely taken up by the teacher in an instructional role, instead of asking the students to do so or at least to make a start in doing so. A more active (and reflective) role of the students on such occasions might be more helpful in keeping track of their learning process.

These problematic aspects of teaching style could, of course, be explained by the fact that in normal, traditional teaching it is far from common practice to explicitly pay attention to the logic and consistency of the teaching/learning process. But this explanation would be really unfair to the teacher. The underlying problem was that the scenario's first version did not clearly stress the reasons for making the local and the global teaching/learning process explicit for the students, and certainly did not offer any overt procedural clues as to when and how to do this. Also the unit's structural design errors noted earlier did not make the task of clarifying the teaching/learning process any easier for the teacher. The conclusion must be that with an insufficiently coherent design of the teaching/learning process, one cannot expect the teacher to amend on the spot the ensuing deficiencies of the teaching/learning process in classroom practice.

Appropriate teacher preparation

Given the above mentioned problematic aspects of the teacher's teaching style, a more appropriate teacher preparation was thought to be necessary before starting off on the classroom trial of the unit's modified, second version. In preparing for the first trial the didactical structure, the scenario and the student materials were thoroughly discussed with the teacher. Although the scenario by nature could be seen as a preview of what might be expected from the teacher in classroom practice, discussing the scenario is no more than swimming in a pool with no water. However, the first classroom trial did not only trigger ideas for the unit's necessary modifications, but also provided material for a more appropriate teacher preparation on the second trial.

In the teacher preparation for the second trial two earlier elements were maintained: discussing the (modified) unit in general and its tasks in detail with the help of the scenario. In between these two elements the teacher was asked to reflect on transcripts of selected instances of his classroom practice during the first trial, representing examples of good and not-yet-so-good teaching with respect to inter-

preting and responding to students' answers and remarks, dealing with disagreements between students in whole-class discussions, and making the global as well as local teaching/learning process explicit for the students. Of course, also the scenario's second version was improved by being far more explicit about the intended global teaching/learning process, about the purpose of each task and its connections with the preceding and forthcoming tasks within this global teaching/learning process, and about the way of introducing a task and using the (expected) outcomes of this task for making a transition to the next task. Therefore, when discussing this part of the scenario (the third element in the process of preparing for the second trial) it was possible to refer to the reflections on teaching practice made somewhat earlier.

Preparing for a trial by discussing the unit in general and its tasks in detail could be considered by the teacher as standard practice when involved in a developmental research project. However, reflecting on instances of his own classroom teaching practice might be somewhat 'threatening'. How did the teacher feel about this preparatory task? His initial response as reproduced in figure 5.5 showed no signs of anxiety. On the contrary, with respect to such a task the teacher displayed a rather favourable attitude.

T It was rather funny to read this. I just can hear myself talking. Anyway, I think it's very good to reflect on your own teaching in this way. Normally, this doesn't happen at all, getting feedback from someone else. But that is really very useful.

Figure 5.5 – Preparatory discussion: the teacher's attitude to the task of reflecting on his teaching practice.

Whole-class discussions – In the discussions about the teacher's teaching style triggered by the selected instances of whole-class discussion – of which the fragments of figures 5.3 and 5.4 are examples – it appeared that the teacher was able to identify the instances in which he is too hasty in interpreting the students' statements or in which he is too dominating. After identifying these instances, he was also able to think of a way in which he could have continued his questioning. However, his problem was that doing this thinking at the spur of the moment right in the middle of a whole-class discussion really is far more difficult. The teacher seemed to have some doubts about his ability to conduct a whole-class discussion in an appropriate way. Therefore, it has been very useful to also select positive instances of whole-class discussion. That is, instances in which the teacher gave the students time to think for themselves, only asked procedural questions stimulating the students to further develop their line of thinking, just repeated or summarised what had been put forward by the students, used disagreements between students to establish questions for further investigation etc. By also selecting and discussing these instances, the teacher might have developed some more confidence in his ability to appropriately cope with a whole-class discussion through making explicit what 'good teaching practice' in the context of this unit actually would mean.

Explicit teaching/learning process – When it comes to making the global teaching/learning process explicit, it appeared that the teacher recognised the importance of giving the students a clear perspective on their learning process by looking back and forward, and that he was able to identify the appropriate instances for doing so. This is illustrated by the discussion fragment of figure 5.6. However, as far as making the local teaching/learning process explicit is concerned, the teacher had some difficulty in understanding 'the problem' of treating two consecutive tasks as disconnected from each other and not making a transition from one task to the next on the basis of what the students have been putting forward. After having been presented an example of how this transition could have been made, the teacher started seeing the point of doing so. This is illustrated by the discussion fragment of figure 5.7. At the same time, however, he did express some anxiety as to his ability to put this into practice.

R Giving students a general idea of what the series of lessons is going to look like and at specific instances explicitly showing where they are ... I take it that's something you don't usually do in your lessons? Or am I wrong here?
T I'm trying to do that more often. In my junior classes it's a bit difficult because we're using a new textbook there, so I don't have an overview myself as yet. But in the senior classes it's easier ...
R This indicates you feel that's important?
T Yes, I can see the importance of that. It seems to me that the students like to see what a chapter is leading up to ... it's clarifying.
R During the previous meeting we have taken a look at the unit's general structure. Now, without going into detail: which instances seem to be suitable for such a looking back and forward?
T The most logical instances are those when you make a transition to a new section ... so, to a new activity.
R Right.
T Last year, as far as I can remember ... I have the impression I did that from lesson to lesson. Something like, ok now what's the intention of this lesson. But now I have to take a broader look ... it kind of supersedes the individual lessons.
R Yes. But also the beginning and the end of each lesson, as far as they don't coincide with a transition to a new activity, are suitable instances for doing that.

Figure 5.6 – Preparatory discussion: the teacher's recognition of his task of making explicit the global teaching/learning process for students.

T Yes ... what you're saying now [in this example] sounds much more coherent for the students.
R That was the reason for selecting this classroom fragment. Now the scenario is paying much more attention to this: how to conclude a task, how to use this conclusion for introducing the next task. That was almost lacking in the old scenario. And then it doesn't come as a surprise that the tasks get disconnected, just like the tasks in an ordinary textbook are disconnected.
T So, clarifying the thread connecting the tasks to them ... that's what I have to do ... And this is indeed indicated in the new scenario?
R Yes, so we can have a look at that in the next meeting.

Figure 5.7 – Preparatory discussion: the teacher's recognition of, but also hesitation about the ability to perform his task of making explicit the local teaching/learning process for students.

The general impression was that this part of the preparatory activities with the

teacher had been rather useful. Reading and discussing the transcripts of selected instances of whole-class discussion was perceived by the teacher as a desired and adequate reflection on his teaching style, and not only with respect to this specific teaching/learning unit. The perceived usefulness of this reflection was enhanced by the fact that it concerned examples of the teacher's own classroom practice in the context of the unit he was actually supposed to teach in a short while. The teacher clearly was open to the expected changes in his teaching style, but had some doubts about his ability to put this into practice. The effort at selecting a balanced collection of whole-class discussion fragments, showing examples of not-yet-so-good as well as good teaching practice, seemed to have been useful in taking away at least part of these doubts. Furthermore, the more extensive procedural specifications in the scenario's second version seemed to accommodate the teacher's request for more support as to what was expected of him in classroom practice.

5.6 Reflection

The presentation of the *ideas* leading up to a didactical structure for the teaching/learning about the topic of decision making on the waste issue in chapter 3 and the consecutive presentation of the resulting *product* in terms of a teaching/learning unit (consisting of a scenario and student materials) in chapter 4 might have given the impression that designing a didactical structure and converting it into a teaching/learning unit reflects a two-step process. This, however, is not the case – as will have become apparent in this chapter about the 'didactical structure in the making'. Designing a didactical structure and converting it into a teaching/learning unit is not a straightforward task. First of all, the ideas leading up to a didactical structure include assumptions about – in this case – the students' existing waste issue knowledge and decision-making skill. These assumptions can to some extent be based on 'just thinking hard enough' about the everyday life situations the students are likely to have experienced, but probably not exclusively. In the present case of developmental research the assumptions about the students' pre-knowledge and skill did also stem from the earlier experiences described in chapter 2. Or, to be more precise: from (re)interpreting data gathered in what might be called an *exploratory* stage of developmental research, involving teachers, students and classroom practice. Secondly, the ideas leading up to a didactical structure include assumptions about the desired (problem-posing) character and the desired (five-phase) structure of the teaching/learning process. In the present case of developmental research also these ideas were partly based on earlier experiences: developmental research on the teaching/learning about the topic of radioactivity (Klaassen, 1995). Furthermore, part of these ideas did develop over time in interaction with actually writing the first version of the scenario and student materials (which in itself is also an interactive process) and in interaction with observing and reflecting on its classroom trial – and even, but to a lesser extent, in interaction with actually writing the modified unit. So,

designing a didactical structure and converting it into a teaching/learning unit is not a straightforward two-step process of putting ideas into practice, but a multi-step interactive process.

Roughly the same could be said about the crucial role of the teacher in carefully guiding the students through their learning process. Before the first classroom trial assumptions were made about an appropriate teacher preparation. But only during the actual first classroom trial it gradually became clear which aspects of the teacher's teaching style were quite satisfactory and which were not – in view of the demands on the teacher in classroom practice, resulting from the way in which the ideas about the desired character and structure of the teaching/learning process were incorporated in the unit. And this classroom practice then paved the way for a more appropriate teacher preparation on the second trial, by having the teacher reflect on selected instances of good and not-yet-so-good teaching practice.

In this chapter an attempt has been made at showing that the assumptions about the outcomes of some key tasks concerning the students' existing issue knowledge and decision-making skill in the modified unit presented in chapter 4 are *grounded* – at least to some extent – in classroom experiences. Furthermore, this chapter has outlined the structural design errors in the unit's first version emerging from a reflection on its classroom trial and the modifications thought necessary for improving on the coherence of the teaching/learning process. And finally, this chapter has indicated in which way the identified problematic aspects of the trial teacher's teaching style have been used for a supposedly more appropriate preparation on the next trial. On these grounds, it is reasonable to expect that this modified teaching/learning unit is at least better, and perhaps even might turn out to be 'good enough' for practical purposes. Then the logical next question is: is it, really? This question is dealt with in the next chapter.

6 The test: the teaching/learning unit in classroom practice – decision making about garbage ...

6.1 Introduction

The preceding chapter has shown that the modified teaching/learning unit as described in chapter 4 is the product of an interaction between the ideas about a didactical structure in chapter 3 and classroom practice during the first cycle of developmental research. Now, the question is: what happened during the classroom trial of the unit's modified version during the second cycle of developmental research? Or, in other words: is this unit – as an elaboration of the didactical structure – 'good enough' for practical purposes? Answering this question remains difficult as long as there is no idea of what the words 'good enough' might mean. The meaning of these words can be found by turning to the scenario. The scenario describes the interrelatedness of the tasks and the intended and expected outcomes of each task in the context of the desired conditions regarding teaching style and learning activity in which this task has to be carried out by the teacher and students. The conditions for and outcomes of each task taken together constitute the intended and expected teaching/learning process. As long as the actual teaching/learning process in classroom practice shows no *major* deviations from the 'path' set out in the scenario, the unit could be considered 'good enough' for practical purposes – that is: for the teacher and students working with the unit, and having the students reach the unit's educational aims. The purpose of this chapter is to describe the classroom trial of the unit's modified version, and to reflect on the results of this trial in order to assess the quality of the unit in classroom practice.

This chapter in section 6.2 first briefly specifies the research design and methodology used during the second cycle of developmental research. The sections 6.3 up to and including 6.7 deal with the five consecutive phases in the didactical structure and the unit as outlined in figures 3.4 and 3.5: *motivation*, *question*, *investigation*, *application* and *reflection*. For each of these phases the experiences during the classroom trial will be described, followed by an evaluation focusing on the question whether or not this part of the unit could be considered 'good enough' for teaching practice given its purpose as stated in chapter 3 (section 3.4). In those cases where the answer to this question is not yet fully affirmative, the section also addresses the still necessary fine-tuning or considerable revision of the scenario and student materials. This evaluation of the classroom trial is concluded in sections 6.8 and 6.9 with a description and interpretation of the results of a post-test questionnaire and an end-of-unit content test, respectively. The chapter concludes in section 6.10 with a reflection on the quality of the teaching/learning process and teaching style during the trial.

The description and evaluation of classroom practice in this chapter at times include rather critical comments, not only on the scenario and student materials, but also on the teacher's teaching practice. It must be noted, however, that most of these comments have been formulated retrospectively in a reflection on the transcripts of what was said and done by the teacher and the students. Retrospectively reflecting on transcripts is relatively easy, compared to the teacher's task of keeping track of what is happening in a busy classroom, of adequately reacting to that at the spur of the moment, and of having to keep in mind the scenario's 'prescriptions' in the meanwhile. The unclarity of the scenario at certain points certainly did not make this task any easier. The critical comments in this chapter should therefore *not* be seen as a criticism of the teacher personally, but as a criticism of the teaching/ learning process – a criticism necessary for reaching this study's aim of arriving at a 'good enough' didactical structure and accessory teaching/learning unit, and of identifying an appropriate way of using this unit in classroom practice.

6.2 Research design and methodology

During the second cycle of developmental research the second version of the unit (scenario and student materials) as described in chapter 4 was developed on the basis of the results of a reflection on the trial experiences during the first cycle outlined in chapter 5.

This second version of the unit was tested a year later than the first version (during the school year 1996-97) at the same school by the same teacher in a grade 9 class with 24 students (13 female and 11 male). These students too were used to teacher-centred whole-class teaching. But compared to the students in the first trial, they had more experience with small-group work on mainly practicals and exercises – as a result of the school's decision to start changing (or: innovating) its educational policy and practice. As a result, the students now also had some experience with working methods such as doing independent research, orally reporting the results to their fellow students in the classroom, and conducting a whole-class discussion – working methods the teacher had ample experience with in his earlier position at a different school. The second trial was prepared in the same way as the preceding one, but now with an emphasis on the reasons why which changes were made during the modification of the unit and with an additional reflection on examples of the teacher's good and not-yet-so-good teaching practice in the context of the unit as indicated in chapter 5.

Again, during the trial all lessons have been observed, video- and audio-taped, and transcribed. This taping and transcribing the classroom trial in the second cycle of developmental research has been limited to the social process of whole-class interaction between the teacher and the students and between the students among themselves. These transcripts have been used as the main source of empirical data

for evaluating the second trial, and for reflecting on the quality of the teaching style and of the teaching/learning process during the trial. There has been no attempt at recording the interactions between students during small-group work. This is because the small-group work just had the 'status' of giving the students some time to prepare their input into the ensuing whole-class discussion. This is not to say that interactions among students during small-group work could not have offered relevant additional information, e.g., for interpreting the interactions at whole-class level. However, regarding this aspect it was thought sufficient to collect the students' workbooks with the results of their small-group interactions. These have been used as additional data, e.g., in those cases where the whole-class interactions were insufficient or even completely lacking.

During the trial the *observations* have been directed at identifying the course of the teaching/learning process in classroom practice. In a *post-trial reflection* these empirical data allow a comparison to be made between the actual and the intended and expected teaching/learning process as outlined in the scenario. As long as the teaching/learning process has been executed as indicated in the scenario, the empirical data are directly useful for answering the question whether or not the unit is 'good enough'. There were, however, two instances of classroom practice in which this was not the case and in which the teaching/learning process really went off-track. In these two instances the impression was that the empirical data, although not directly useful, still could be used for answering the question of the unit being 'good enough' by giving them a specific treatment. The first instance concerned a messy whole-class discussion with the aim of establishing the questions for further investigation. In order to be able to extract the empirical support from this part of classroom practice, the data regarding the teacher's and students' utterances had to be re-sequenced by using a method of so-called *reconstruction*. This method will be described and elucidated when dealing with the question phase of the unit in section 6.4. The second instance did concern the content and presentation of the students' argued point of view in decision-making situations. In this case it was not so much a matter of the teaching/learning process going off-track, but of a stagnation not foreseen by the scenario. In order to come to understand what did happen in classroom practice and how this stagnation could be prevented in future, the data regarding the students' utterances had to be interpreted by using a method of so-called *reformulation*. This method will be described and elucidated in section 6.6, dealing with the unit's application phase.

The second classroom trial has been concluded by administering a *questionnaire* and a *content test* in order to get an impression of the students' perception of the teaching/learning process and the unit's learning effects. In sections 6.8 and 6.9 the character and status of both instruments as well as the results will be discussed.

During the post-trial reflection the interpretation and – where necessary – the reconstruction and reformulation of the empirical data as well as their implications for answering the question whether or not the unit could be considered 'good enough' for practical purposes were extensively discussed with an expert researcher until consensus was reached.

Small-scale testing
From the above description it can be gathered that the unit has been developed and tested within a small-scale and qualitative research design, with just one teacher teaching just one of his classes of target population students. The rationale for the small-scale testing is that this study is primarily concerned with 'getting a grip' on the intricacies of teaching the topic under consideration and of the problem-posing teaching/learning process that was chosen as a starting-point. This means that the study not so much aims at a product in terms of a unit that can be widely used by a variety of teachers, but primarily focuses on learning about the didactics of the topic at hand. For such 'didactical learning' a small-scale test will provide ample information, provided that the teaching/learning interactions at classroom level are closely followed, documented and interpreted. The rather labour-intensive character of such a task provides an additional reason for small-scale testing. This is not to say that the scale of the trial should be limited to the absolute minimum of one teacher teaching one class. A scale of one teacher teaching two classes might even be preferred, especially if there is a small phase difference between the trial in these two classes. In that case, teaching experiences in one class can be used productively for improving teaching practice in the second class. However, the teacher concerned was just not teaching more than one class of target population students.

The 'didactical learning' aimed at in this study will eventually result in a coherent package of didactical structure, scenario and student materials for the teaching/learning about the topic under consideration, supported by empirical data showing that the intended teaching/learning process can be realised in classroom practice. It is such a tested package that could meaningfully be tested on a larger scale, involving a variety of teachers and students and adopting a more quantitative/ comparative research design to further establish the validity of the didactical structure and to assess its learning effects.

6.3 The motivation phase: inducing a global motive

In chapter 4 (section 4.2) it was stated that the first teaching/learning activity has to induce in students a sense of purpose for at least beginning to study the topic at hand, and to provide them with a first sense of direction concerning where their study will lead them to. This purpose of the unit's motivation phase is supposed to be realised through the design of the scenario and the tasks in the students' workbook. The question to be answered in this section about the trial of the unit's motivation phase relates to its purpose and its design, and will therefore be called a *design/research question*.

The design/research question to be answered in this section about the trial of the unit's motivation phase as described in chapter 4 (section 4.2), given the purpose of this phase, is:

- *Does this teaching/learning activity induce in students a sense of purpose for at*

least beginning to study the topic at hand, and does it provide them with a first sense of direction concerning where their study will lead them to?

Classroom trial

During the trial of the modified version of the unit, the three tasks in the motivation phase went roughly as planned and expected in the scenario.

Task 1: Decision-making situations – In the whole-class discussion following the small-group work on task 1 the students are able to identify the personal environmental decision-making situations, and agreement is reached on the situations 2, 4, 8 and 9 (figure 4.1) as representing decision-making situations in which you could, through your own behaviour, contribute to a better environment. However, there are some unforeseen 'diversions' in the whole-class discussion. First of all, the students are searching for an environmental connection in decision-making situations that are not meant as such. An example is the decision-making situation about buying a compact disc. The students refer to pollution during the production process. In the ensuing discussion the teacher's reaction to remarks like these is not quite adequate: 'No, stop. That's not the point ...' and 'Well, if we are going to argue like that ...'. In doing this, the teacher gives the students the impression of their contributions being incorrect, while they do make some sense. Careful questioning by the teacher might have easily made the students recognise that production of compact discs indeed would have an environmental impact, but that in this respect choosing between a Michael Jackson and a Metallica compact disc doesn't make any difference. Secondly, the students come up with an unexpected interpretation of their own action perspective. An example is the whole-class discussion on the decision-making situation about the high-speed train, as reproduced in figure 6.1.

T Ok, let's see what you have found. This first decision-making situation [about the high-speed train], is that a situation that has to do with the environment?
S_1 Yes.
T And can you yourself make a contribution?
S_1 No.
T No. So it is a decision-making situation that has to do with the environment, but you yourself cannot make a contribution.
S_2 Go on strike.
S_3 You can go there and put up signs, isn't it? Like: against, against ...
T Ok. So you can demonstrate. Then you make a contribution ... But that's not really in everyday life ... Or is it?
S_3 As long as it's not already there, it is.
T But once it's there, you cannot make a contribution any more.
S_3 No.
T Ok. We don't agree completely. You could demonstrate, like he [S_3] says ... Did anyone of you have the same, such a contribution? Two, three ... Let's continue with the next decision-making situation.

Figure 6.1 – Whole-class discussion: an unexpected interpretation of the students' perceived personal action perspective.

Recognising this decision-making situation as one to be selected in this task would mean including it in the next task. However, this would cause some problems, as this situation does not fit very well into the second task, as it does not concern the use of raw materials, energy or water in a direct way. What the teacher therefore is trying to do is dissuading the students to select this decision-making situation – in which he does not seem to really succeed in a for the students convincing way, as the same kind of action perspective keeps turning up with respect to other decision-making situations somewhat later in the same whole-class discussion. This forced adherence to the scenario's predictions and expectations – of which this is only one example – might give students the impression that they are wrong, while this is not at all the case.

Task 2: Environmental decision-making situations – By selecting only those decision-making situations on which 'agreement' is reached in task 1, a transition to task 2 is possible. The whole-class discussion roughly goes as planned, as can be seen from the fragment reproduced in figure 6.2, dealing with the selected decision-making situation 4 (filament or energy saving bulb) from task 1.

T Let's see what we found out ... Who has worked on decision-making situation 4? [S_1], tell us: what are the two alternatives in this situation?
S_1 An energy saving and a filament bulb.
T Right: energy saving and filament bulb. Has this decision-making situation to do with the use of material, or water, or energy?
S_1 Energy.
T Energy. The third question: does the use of the material, water or energy produce waste?
S_1 Yes.
S_2 That isn't the third question ...
T Oh sorry: where does the material, water or energy come from? Energy in this case, where does that come from?
S_1 From the power plant.
T Power plant. But where does this power plant get its energy? ... Who can help him [S_1]?
S_3 From water and wind.
T Water and wind ... Could you explain that? Why water and wind?
S_3 Wind turbines
T Wind turbines. Are there any wind turbines here in Utrecht?
S^s Sure.
T And a normal power plant like at Lage Weide, in the city of Utrecht. How is electricity made in such a power plant? Do you [S_4] know how?
S_4 Yes: burning of chemical fuel.
T What is that: chemical fuel?
S_4 Eh ... oil, gas ... and wood.
T Yes. Wood probably not, there in Utrecht. Coal could be ... But at Lage Weide they burn natural gas. Now back to the question for a moment: where does the material, water or energy come from? Energy in this case, the natural gas. Where does this natural gas come from?
S_5 Out of the ground.
T Out of the ground. Ok, is extracted from the ground. Then this last, fourth question: does using this natural gas produce waste?
S_1 Yes.

T And what kind of waste is that?
S_1 With that gas?
T Yes. In order to have that bulb give off light, we need electricity. This electricity comes from that power plant. And there they burn gas – that's where we were. So, does burning gas produce waste?
S^s Yes, a bit/Smoke.
T Smoke? What is there in that smoke?
S_6 CO_2.
T CO_2, carbon dioxide. So there is waste indeed, although often you cannot see that very well. Any more waste substances in that smoke?
S_7 Smog.
T Smog can be produced. Ok, we'll continue with the next decision-making situation ...

Figure 6.2 – Whole-class discussion: analysing selected decision-making situations.

In this whole-class discussion the teacher clearly tries, by using the suggestions for further questioning as outlined in the scenario, to focus on the expected outcome of this task by carefully guiding the students through questions asking for further clarification, through repetition of students' reactions (thus making them known to the whole class), through procedural interventions such as summarising etc. Another important aspect – not included in the whole-class discussion fragment of figure 6.2 – is that the teacher at some points signals a disagreement between students or a simply not knowing (for sure), without a regression into a traditional teaching mode of 'telling the students the right answer'.

The discussion is concluded by the teacher with a kind of summary as reproduced in figure 6.3, in which the analogy between the discussed decision-making situations is being made explicit – as suggested in the scenario. In retrospect it might have been better to have the students themselves do this summarising, guided by a question to be put forward by the teacher, such as: 'In which respect are these decision-making situations similar?'.

T Ok. In all these decision-making situations you need something out of the environment. You extract something from the environment. And some time later you dump it into the environment. Probably in another place, but you dump it somewhere in the form of waste. Yes? Now let's have a further look at one of these decision-making situations. And then we choose the one that deals with packaging waste. Which one was that?

Figure 6.3 – Whole-class discussion: the teacher's summary of the similarity between the analysed decision-making situations.

The task's purpose of establishing the analogy between the selected environmental personal decision-making situations seems to be reached to a reasonable degree. However, this is not the case for the task's second purpose of preparing a provisional limitation of the topic to decision making about packages. The idea that decision making about packages could be seen as exemplary for the wider range of selected environmental decision-making situations is not made explicit, neither at the end of task 2 nor at the beginning of task 3. A look at the scenario at this point

reveals some discrepancy between the scenario's general description of the didactical structure and the more specific description of expected teaching practice. This discrepancy at least partly explains this 'omission'.

Task 3: Packaging decision-making situations – The purpose of task 3 is to reinforce the students' motive for learning about packaging by making them realise that this kind of decision-making situation occurs more frequently than might appear at first sight. In this respect, the yield of this task is a bit disappointing. First of all there appears to be confusion between double packaging of a product and packaging alternatives for a product. This confusion is not used productively to clarify the kind of decision-making situations featuring in the unit. Secondly, in the whole-class discussion only a jar/can-situation is being put forward as a second example. Analysis of the students' workbooks reveals this decision-making situation to be prominent, be it for a range of products, with a plastic/paper-situation in second place. During the first trial a collection of empty packages on display triggered a far more extensive response to a similar question somewhat later in the unit.

In concluding the discussion on task 3 the teacher gives the students a preview of their prospective learning process, as reproduced in figure 6.4.

T Well ... a better environment, you could make a contribution through choosing between packaging alternatives. Packages have environmental implications ... the waste you dump has an environmental impact. That's what we're going to look at in section 2, starting at page 9 of the workbook: look at the environmental impact of packages. Now suppose there is a number of things we don't know – some moments ago we had a discussion like that, you remember: what happens with this milk carton, is that fit for recycling or not? Well, some things we don't know. Or we disagree about.

S_1 A milk carton isn't recyclable. [Inaudible for T]

T That means we're stuck with questions. Questions to which we can find an answer ... Those we will call research questions. With the help of these reference materials or experiments we can find those answers. That's what we're going to do in section 3, starting at page 17. If all goes as planned, we then have an answer to everything we have to know, and then we would be able to make a thoughtful, well argued choice between packaging alternatives: because of such and so we choose this, or that. Ok? Now suppose you are able to do that for packages, then maybe you can do the same for water or energy we've just been talking about.

Figure 6.4 – Whole-class discussion: the teacher's preview on the student's prospective learning process.

By relating to earlier disagreement between students the teacher succeeds to give the intended preview, although it might have been better if he had explicitly told the students that he was going to do so. Problematic might be his last remark about the other decision-making situations, as the exemplary character of decision-making situations concerning packages featuring in the unit has not been introduced earlier.

Evaluation

The above-given description and illustration of classroom practice will first be discussed in the light of the design/research question about the unit's motivation

phase. Then the question will be answered. In conclusion, some ideas about a necessary fine-tuning of the scenario will be presented.

Discussion – The motive for starting to learn about packaging waste does not yet come forward in a sufficiently clear way: the exact character of the decision-making situations featuring in the unit is not yet made sufficiently explicit, packaging decision-making situations are not yet presented strongly enough as exemplary for a wider range of environmental decision-making situations, and the range of packaging decision-making situations put forward by the students is still far too limited.

A first idea of what the unit is aiming at most likely has come across: the unit deals with environmental decision-making situations, limited to decision-making about packages – and in the context of these decision-making situations it seems logical for the students to find out if they already know enough about packages, if not to search for adequate information, and if found to apply this in decision-making situations. The generalisation to other environmental decision-making situations probably is still a bit unclear for the students. So, the students' view on their prospective learning process is still not completely clear, but seems far more complete than has been the case in the first trial – and sufficient for 'a first idea'. Especially the decision-making context has been dealt with rather explicitly. As far as this decision making relates to contributing to 'a better environment', it is still unclear what 'a better environment' exactly is. But by looking at environmental decision-making situations from the point of view of extracting 'something' from and adding 'something' to the environment the introduction of environmental criteria for comparing packaging alternatives in the didactical structure's next phase has at least been prepared to a sufficient degree.

The scenario has been executed by the teacher roughly as intended and the students react to the tasks roughly as expected. This could be seen as an indication that the design of the unit's motivation phase meets its purpose. There are, however, no instances of classroom practice in which this becomes explicitly clear in terms of the students' utterances. The fact that they respond to the teacher's questions in a way that could be characterised as enthusiastic and to the point provides an indirect support for an induced motivation to study the topic at hand. A more interactive approach from the part of the teacher in concluding the discussion on task 3 might have yielded some empirical data showing that this has been the case indeed.

Conclusion – The answer to the design/research question for this first phase of the didactical structure is not yet a clear yes, but in any case far more affirmative than the clear no after the first trial. However, it is most likely that the answer to this question would be affirmative after some fine-tuning of the scenario related to the deficiencies outlined above, without changing the tasks this first teaching/learning activity in the unit consists of. The conclusion could then be that this elaboration of the motivation phase of the didactical structure would indeed be 'good enough' for practical purposes (teaching practice), provided that the following ideas are going to be incorporated in the scenario.

The scenario should be more explicit about how to deal in teaching practice with the non-environmental and the non-personal decision-making situations in task 1. In the case of non-personal environmental decision-making situations it would be better to recognise the action perspective of demonstrating (and voting) as mentioned by the students, followed by a productive use of these remarks (if they are made) to focus on the specific kind of decision-making situations featuring in the unit: decision-making situations related to the students' own everyday life at school and home, and not the more general environmental action-taking such as demonstrating (and voting). The scenario should also be more explicit (and show more consistency) about the intended transition from task 2 to task 3, so that students start seeing decision making about packages as exemplary for a wider range of environmental decision-making situations. This would not only explain the focus on packaging decision-making situations in task 3 (and a large part of the remainder of the unit), but would also open up the opportunity to provide the students with a complete and understandable preview on their prospective learning process. Finally, the scenario should be expanded with some ideas for summoning a wider range of packaging decision-making situations in task 3. One of these ideas could be displaying a carefully selected collection of empty packages in the classroom. Based on experiences with a similar task in the first trial, it can be expected that these packages will trigger the students' thinking about alternatives for the packages on display – thus arriving at the intended wider range of packaging decision-making situations.

6.4 The question phase: establishing a knowledge need

The design/research question to be answered in this section about the trial of the unit's question phase as described in chapter 4 (section 4.3), given its purpose, is:

- *Does this teaching/learning activity make students become aware of a need for extending their knowledge in the light of the global motive, and does it have them formulate this need in the form of their own questions for further investigation?*

Classroom trial

During the trial of the modified version of the unit, most of the six tasks making up the question phase went roughly as planned and expected in the scenario. The task of identifying the questions for further investigation in a decision-making context at first sight seemed to go off the track. However, a *reconstruction* of what might have happened on the basis of what actually happened will be used to assess whether or not the elaboration of this phase in the didactical structure could be considered 'good enough'.

Task 4: Wrapping up and packing off – The whole-class discussion following the audio-visual information is rather lively and from time to time a bit unstructured as a result of the students' enthusiasm in contributing to the discussion. As expected in

the scenario, what is being put forward by the students relates to the environmental problems of dumping and burning waste (depletion and pollution) and the solutions for these problems (prevention, recycling and separate collection of household chemical waste) – even without questioning by the teacher. On top of that, there is even more: flue gas filtering, limitations of recycling (through quality degradation), choice of material in designing packages (no laminates), and paying garbage-collection fees dependent on the amount of waste produced. What does not come forward is the difference between reusing and recycling and the aspect of renew-ability of raw materials. The next task will show whether or not students are able to deal with those aspects when constructing a model of the waste issue.

Task 5: Summary – Solving the waste issue puzzle is done at a much earlier stage than during the first trial. It appears that some students now have problems in getting started. Asking those students to consider what happens with empty packages is enough to put them on the right track. Somewhat later some students experience difficulty in coping with the difference between reusing and recycling. The whole-class discussion about the puzzle's solution goes rather unproblematic. It is remarkable that students during this discussion out of themselves start to identify 'things we don't know', as reproduced in figure 6.5. This might be an indication that students are aware of the intended teaching/learning process.

T Yes, that [household chemical waste] is collected separately. Once a month or so it is collected, or you can return it to a collection point. That depends on where you live.
S_1 Then where does it go to?
T Then what is ... Where does it go?
S_2 That we don't know.
T Right, we don't know. So that's one of the things to investigate in our research: what happens with the household chemical waste?

Figure 6.5 – Whole-class discussion: students (already) identifying research questions.

Task 6: A better environment – Task 5 is immediately followed by a whole-class discussion triggered by task 6, and here things start to go off-track. First of all, the transition from task 5 to task 6 is more or less forgotten, thus obscuring the local coherence of the teaching/learning process. Secondly, the teacher starts asking for the points to consider in decision-making about packages in the light of the puzzle's solution, without first focussing on the environmental problems as intended. It is thus logical that students start looking at the solutions for contributing to 'a better environment' in the upper half of the puzzle's solution, instead of the intended lower half. This results in a forced effort by the teacher to bend the students' utterances towards the intended stating of environmental problems and connected environmental criteria to be used in decision making about packages.

Task 7: ... starts with choosing a package – Again, the intended transition from task

6 to task 7 is lacking. Therefore, it will be more difficult for the students to understand *why* they are asked to compare the two packaging alternatives, neither in the sense of the unit's contents (why is comparing packages on environmental criteria useful?) nor in the sense of the teaching/learning process (do we know enough to do this comparing sufficiently well?).

During the small-group work a lot of questions emerge as a result of a lack of knowledge about criteria-related properties of packages and packaging materials, such as the recyclability of milk cartons and the reusability of milk bottles. Also there is the question of what to write down if the comparison of the alternatives on a criterion results in a draw. However, during the ensuing whole-class discussion these questions do not turn up. It appears that the students agree on both comparisons. The implicit conclusion would therefore be that there is no need for any extending of knowledge, and the rest of the unit is superfluous ... finished. The lines of questioning suggested (and therefore expected necessary) in the scenario to summon disagreements between students on their comparisons are not being used by the teacher. This lack of questioning by the teacher seems to suggest to the students that the comparisons put forward are largely correct, implicitly providing them with the correct answer to their own questions during the foregoing small-group work. At a later stage, when dealing with task 9, this problem of lacking questions for further investigation is addressed to some extent, as the teacher in the meantime has become aware of the fact that the teaching/learning process has gone completely off-track.

Task 8: Packaging materials – As a result of what happened (or better: what did not happen) during the whole-class discussion about task 7, task 8 cannot be very logical to the students. However, they do not have any problem in identifying the five most often used packaging materials as intended and expected.

Task 9: Research questions – The purpose of task 9 was nothing more than writing down the already stated questions for further investigation by combining the results of tasks 7 and 8. As task 7 did not result in any such questions, this problem has now to be addressed first. In an inserted whole-class discussion – which should have taken place in task 7 – questions for further investigation emerge about the number of times the bottle could be reused, the recyclability of a carton, the pollution by a carton in the case of dumping or burning, and the depletion of wood and oil (as being raw materials for the carton and the bottle). Some opportunities for formulating questions for further investigation are missed, and on some occasions an emerging disagreement between students is settled by the teacher. The whole-class discussion is summarised by the teacher in terms of the intended research questions, which do seem to encompass what has been put forward by the students throughout the discussion.

The question phase of the unit is concluded by looking back and forward, as reproduced in figure 6.6. The teacher asks the students to do this, as indicated in the scenario. It appears that looking back provides the students with some difficulty, as was to be expected when considering the rather mixed up and confusing teaching/

learning process during the foregoing three tasks. However, when asked to look forward there seems to be some understanding of the global teaching/learning process. However, in this understanding the decision-making context is not very prominent, probably as a result of the research questions not having emerged from the decision-making situation in task 7 but more or less 'out of the blue' at a later stage.

T You see ... in these lessons we have taken a look at what is better for the environment. You have seen that we already know quite a lot about that. But we also have a lot of questions. Now let's look back at the last two lessons for a moment. Eh ... what did we do, and why is that important? Who could summarise that?
S_1 Else we die.
T How come, else we die?
S_2 Well, if there wouldn't be any raw materials left, then you could almost ... Well, then everything goes wrong.
T Ok. So we're stuck with depletion of raw materials, and then things start getting difficult. What starts getting difficult then? Could you explain that somewhat more clearly?
S_2 Life.
T Life gets more difficult.
S_3 You have to be more aware of what you're doing.
T Could you explain that somewhat better?
S_3 For example, not just dispose of something by throwing it into the garbage bag ... that others – like when you have children [inaudible].
T So that children ... your children or our children ... Yes ... What else did we do during these last lessons? ... Has anyone got an idea of what we are going to do in the oncoming lessons?
S^s Well, no/Investigating/Answering those questions.
T Investigating. What are we going to investigate?
S^s Those questions.
T We've got a series of questions. Those we are going to investigate. And then? What's the use of that?
S_4 Then we have answers to those questions.
T But what's the use of that? Then what do we know? Why is it important to have answers to these questions?
S_5 Then you can do something about it.
T What can we do then? ... What's the use of knowing whether paper is recyclable and how this is done? And whether such a carton is recyclable and whether that happens? What's the use of that knowledge?
S_6 Well, then we know we have to buy a bottle with such a [inaudible].
T So then we know when we're in the shop which package we have to take, and which package not.
S_6 Yes.

Figure 6.6 – Whole-class discussion: students looking back and forward on their learning process.

Evaluation

The above-given description and illustration of classroom practice will first be discussed in the light of the design/research question about the unit's question phase. Next, the identified deviation from the scenario will be 'repaired' by making a *reconstruction* of what has actually happened during the classroom trial in this phase

during tasks 7 up to and including 9. Based on this reconstruction a *conclusion* will be drawn concerning the question at hand, followed by a *reflection* on the method of reconstruction.

Discussion – The summoning and structuring of the students' general issue knowledge roughly goes as expected without any major deviations from the teaching/learning process as outlined in the scenario. Using this structured general issue knowledge in defining the environmental criteria for comparing packaging alternatives, however, is less of a success. The same goes for making students aware of a need for extending their specific issue knowledge in the light of the global motive, as is the purpose of the unit's question phase. The students do become aware of a need for extending their knowledge in terms of criteria-related properties of packages and packaging materials, but not in the light of the global motive. So, not in the light of *decision making about packages*. The indication that the intended teaching/learning process gets off-track in this respect can be found in the considerable difficulty the students have with the decision-making aspect in looking back and forward on their learning process so far. The students do become aware of a need for extending their specific issue knowledge, but this awareness does not cover the expectation that the (to be) extended knowledge would enable them to compare packaging alternatives on the environmental criteria in a better way.

During this second trial the problem-posing character of the teaching/learning process therefore is not yet sufficiently clear. Still it seems that the elaboration of the didactical structure so far has improved considerably as compared to the unit's first version. It also seems that students are more aware of their prospective and actual learning process, which could be considered as an improvement as compared to the first classroom trial in which such awareness seemed to be almost lacking.

There is, moreover, reason to believe that if the teacher's guidance of the teaching/learning process had been as 'prescribed' by the scenario, it would not have gone off-track and instead would have remained on the course outlined by the scenario. That is, the scenario would have turned out 'good enough'. Now, it is clear that if the teacher's guidance is not as 'prescribed' by the scenario, the process going off-track does not count *against* the scenario. But how could it possibly count *in favour of* the scenario? There is reason to think it can, at least in this case. For what seems to be the case is that things happened in the wrong order. The whole-class discussion that was supposed to take place in task 7, for instance, took place in task 9, where it missed part of its point. The idea, therefore, is to try to put everything in its right place by using a method of *reconstruction*.

Reconstruction

The method of *reconstruction* involves cutting and pasting of what has actually happened during the classroom trial into a sequence of what might have happened if the guidelines set out by the scenario had been followed in classroom practice, adding some teacher interventions related to these guidelines, and – in a very restricted way, based on the observations of the students' small-group work on the

tasks concerned – adding a most probable student reaction to these additional teacher interventions. In the reconstruction presented in figure 6.7 the additional interventions and students' reactions to these interventions have been printed in italics.

T *Now we know from task 6 which points to pay attention to if we want to contribute to a better environment by choosing between packages. These environmental criteria are: less depletion and less pollution. Now, here I've got two packaging alternatives for the product milk: a plastic bottle and a carton [shows both packages]. Let's try in task 7 to compare those two packages on those two environmental criteria - just to see if we already know enough for being able to make a choice. Because that is what we have agreed upon at the end of activity 1: first see what we mean with 'a better environment' – and that we now know – and then see if we know enough about the environmental impact of packages. So,* you're standing in the supermarket, you have to buy milk ... and you can choose between these two different packages [shows both packages]. You can choose - maybe not in all supermarkets – between milk in a carton and milk in a bottle. Now have a look at page 12. Your task is to complete that table. You see: the product is milk. Milk can be packed in a bottle or a carton. The first question is: what is this [shows milk bottle] made of?

S_1 Of plastic.

T Yes, that you can write down in the table. And what is this [shows milk carton] made of? Write that down also.

S_2 Carton

T Next ... in the rest of the table we are going to compare these two packaging alternatives on the environmental criteria, depletion and pollution. Those criteria, you can write them down ... and compare them on these: what about depletion by a carton as compared to a bottle, what about pollution by a carton as compared to a bottle. Is that clear? Then, have a try.

[Small-group work]

T Not such an easy task, isn't it? In going around the classroom, I see a lot of things to which we don't know the answer: is that so or not, what about this? Well, that's just the purpose of this task – we'll make an inventory in task 9 ... of all the things to which we don't have an answer or where we're not sure about the answer. We'll call those research questions. But let's first see if we agree on this. Two environmental criteria on which you can compare a bottle and a carton: depletion and pollution. Yes? Ok. What is a bottle made of [S_3]?

S_3 Of plastic.

T Is that the only material a bottle is made of?

S_3 No, also paper.

T There's also paper, a wrapper. Anything else? No? What is a carton made of?

S_3 Carton and plastic.

T Ok. The first environmental criterion – depletion – what did you write down when comparing the carton and the bottle [S_4]?

S_4 The carton is depleted more quickly.

T In what way? Why? Could you explain?

S_4 It cannot be recycled anymore or something like that.

T It cannot be recycled. Everyone agrees?

S_5 Yes.

T But how come? In the previous lesson I heard someone say to throw it in with the waste paper for recycling.

S^s Yes/But there's plastic around it/Just goes into the garbage bag.

S_6 Quite often on these containers it says, eh ... no disposal of milk cartons.

T Ok. *But just a minute ago I heard yes and no. Apparently we don't agree, or not everyone knows for sure. Then we're stuck with a question:* is a milk carton recyclable?
S_6 No.
S_5 But we just don't know that, do we?
T Yes, do we know that? Is a milk carton recyclable?
S_6 No, because there's plastic in it and carton also ... and both can't be recycled at the same time, is it?
T There's plastic in it, and carton on the outside. Both cannot be recycled ...
S_7 It can't be melted, because there's plastic in it which then burns.
T Ok. So that's *still* a question: is it recyclable? *Because maybe this carton and plastic can be separated. That could be something to investigate in one of the following lessons. And if separation appears possible, then the carton could be recycled. And maybe also the plastic. It seems we don't know that either. But let's return to the environmental criterion of depletion:* what about depletion *if recycling would be impossible*? What is it made of ... carton.
S_8 From trees.
T Trees. What about those trees?
S_9 They are cut down.
T Are we then dealing with depletion?
S_9 Yes, because the number of trees gets less and less.
T The number of trees gets less and less. Do you [S_1] agree?
S_1 Yes.
T Yes. Everyone agrees?
S_2 Well, new trees are being planted.
S_3 Yes, but that takes a long time.
T Replanting takes a long time. So here we're also stuck with a question: what about depletion of the raw material for carton. Are those trees growing quickly enough to replace what has been cut down?
S_3 No.
T *She [S_2] apparently thinks of yes, and for you it's no. So,* we don't know. There's another question.
S_3 But then how do you find out?
T That's what we're going to investigate. But for the time being we'll just write down the questions. What about the other one: depletion of plastic? What's the raw material for making plastic?
S_4 Oil.
T What about depletion of oil? Does that grow?
S^s Yes [hesitatingly]/No, can also get depleted.
T Is oil renewable or not?
S_5 No.
S_6 [inaudible]
T In about two hundred million years it will return? Is that of use to us?
S^s No/Yes, of course ...
T *Also here we're apparently stuck with questions: I'm hearing yes and no where it concerns raw materials for carton and plastic.*
So, in summary: it is not completely clear whether or not milk cartons are recyclable, and if they are not recyclable it is also not completely clear whether or not the raw materials are running out – because both raw materials are renewable. But this concerns still only the carton. What about the bottle [S_7]?
S_7 That can be recycled.
T Recycling. How does that happen?
S_8 Return it to the supermarket.
T Do we call that recycling?
S_8 No, but then they take it along, and then ...
T And what do we call that?
S_8 Reuse.
T So it's being ... it's a returnable package, isn't it? Recycling, that's what we do with eh ... empty wine bottles. Those you put into the bottle bank. This [shows milk bottle] is being cleaned and refilled.
S_8 Ah yes, ok.

T *But what about depletion of raw materials for such a bottle?* How many times ... is it never thrown away? How many times can we reuse it?
S_9 Yes eh ...
T Does anybody know that? ... So, no. That's what we have to find out: how many times can such a bottle be reused.
S_1 But can't it be reused as many times as you want?
T Is that so? I don't know. We'll have to find out ... Do you know it?
S_1 No.
T That's what you suppose, I guess. Ok, let's bear that in mind for a while. *Now if such a bottle can be reused only a couple of times, then what happens with it afterwards? And are we then dealing with depletion of resources?*
S^s *[disagreeing/not knowing]*
T *Well, that appears to be not so easy ... comparing the carton and the bottle on the environmental criterion of depletion.*
At the start it looked rather simple: the carton gives more depletion of raw materials, because the carton is not recyclable and the bottle is being refilled time and again. But it's not as simple as that: we don't know enough for being able to compare the carton and the bottle on depletion. We are stuck with a couple of questions about that: maybe the carton is recyclable after all ... and if that's not the case, then it still is the question whether wood as the raw material for carton will run out, because wood is a renewable raw material ... trees can be replanted, but does that happen and are they growing up quick enough?
Regarding the bottle we have something comparable: how many times can it be refilled, what happens with it afterwards and does that cause depletion of oil as the raw material for plastic? Those are all questions to which we have to find an answer in order to be able to compare the carton and the bottle on the environmental criterion of depletion.
And what about *that second environmental criterion:* pollution ... if you [S_2] compare a carton and a bottle on pollution.
S_2 The bottle is being recycled, and that doesn't have much impact on the environment.
T Yes? Is there more to say about that?
S_2 It's eh ... less detrimental to the environment. Because if you throw away the carton ...
T Because? Why is throwing away the carton detrimental to the environment?
S_2 Then it gets burned or dumped.
T And then?
S_2 If it is burned it gives off CO_2 or something like that.
T Then CO_2 is being released.
S_2 By that plastic.
T Is that so? Does that plastic cause a release of CO_2?
S_3 No way.
T Then what? You [S_3] say: no way. What about this pollution? Suppose you dump or burn it. Then what happens? We're then stuck with pollution, has been said. In what way? What kind of pollution? ... Is there any pollution? ... *Do we know that?*
S^s *[disagreeing/not knowing]*
T *And then that bottle ... is being refilled. Does that give pollution? ... What has to happen to the bottle before it can be refilled?*
S^s *Cleaning.*
T *And does that give pollution?*
S^s *[disagreeing/not knowing]*
T *Ok. Also concerning pollution we don't know enough yet about those two packages: how polluting is dumping and burning of a milk carton really – if that is what happens. And how polluting is the cleaning of those returnable bottles? Which of those two is the best choice with respect to pollution ... that's something we cannot yet tell.*
Now which conclusion can we draw from this discussion in task 7 about comparing the two packaging alternatives ... the carton and the bottle ... on those two environmental criteria depletion and pollution?
S^s *We don't know enough about the packages.*

T *Yes: we still don't know enough about those two packages ... about depletion of raw materials, about pollution through dumping or burning or refilling ... in order to be able to choose. And this probably not only concerns the carton and plastic we've been dealing with so far, but also other packaging materials. And that brings us to task 8: about which packaging materials do we have to know more if we're presented with other decision-making situations? Therefore*, let's have a look at the next task. I've got a collection of empty packages on display here. You'll probably be able to think of more examples considering what you use or what's in the cupboard at home. Which five materials are used most often for packing [S_4]?
S_4 Plastic, carton, glass, aluminium and tin-plated steel.
T Plastic, carton, glass, aluminium and tin-plated steel. Those are all present in this collection of packages. Aluminium ... what is that used for?
S_4 For a can of coke.
T A can of coke. Everyone agrees? Has somebody thought of still other packaging materials?
S_5 Yes: foil.
T Foil. What is foil made of? ... There are different kinds of foil at home. Which foil do you mean?
S_6 For packages of coffee.
T This [shows coffee package]? This kind of foil? What kind of material is this?
S_5 Plastic?
S_6 Aluminium.
T Aluminium foil. And aluminium we had already listed as one of the five packaging materials. Did we forget other materials?
S_7 No.
T Ok. We already know a lot about packaging materials. We have put all that knowledge together *in the puzzle's solution in task 5*. And we also know ... if we want to contribute to a better environment *through our choice between packaging alternatives*, then we have to pay attention to these two environmental criteria [points them out on blackboard]. *And we know the packaging materials concerned*. But *about those packaging materials* there is a lot we don't know yet. In the meantime *while working on task 7*, we have generated a lot of questions. The idea is that we write down those questions in task 9. First, try to do that by yourselves. Those questions we call research questions ... What did you say [S_8]?
S_8 Such as: what happens with household chemical waste?
T Yes, that's such a question.

[Small-group work]

T Ok. Everybody ready?
S^s Yes/no.
S_9 Now what was that question about milk?
T About milk? About a carton? A bottle?
S_1 How many times a bottle can be reused.
T Ok: how many times can a bottle be reused. That's a question. More questions [S_2]?
S_2 What happens with household chemical waste? And eh ... is a milk carton recyclable?
S_3 What are batteries made of?
T Right, we also had that as a question.
S_4 Which is the most environmentally sound, and what are they made of?
T What do you mean? Those materials?
S_4 Yes. Which are used most often. Which is the best one for the environment.
T Ah ... of those materials used for packages. *And what do you mean exactly with the best for the environment?*
S_4 *Well eh ... depletion and pollution*. And what is strongest, what lasts the longest.
T What do you mean? You mean the recyclability of the package?
S_4 Yes.

T Ok. Very well. Ok. Any more questions?
S_5 How do we recycle glass, paper and plastic.
T Right. I wonder, yes. How do we do that ... if you throw a non-returnable bottle in the glass recycling container, how do they make new glass out of that? And what about plastic? If this one [shows bottle] is returned ...
S_6 That's being melted and ...
T More? ... *Well, I think he [S_4] has summarised it rather well. Because as a research question he says something like: which material is best for the environment ... what about depletion of raw materials and pollution through dumping and burning for each of those five packaging materials – and what about recycling and reusing, because that influences depletion and pollution. So, let's write down that one:* what about the five most often used packaging materials ... What were those materials [S_7]?
S_7 Tin-plated steel, plastic, glass, carton ...
S_8 And aluminium.
T Ok. What about those five most often used packaging materials as regards to ...[writes on blackboard]. Well, and then there are a number of points: depletion of raw materials, pollution through dumping and burning, and reusing by refilling or recycling.

Figure 6.7 – Reconstruction of whole-class discussions during the classroom trial of tasks 7 up to and including 9.

In this reconstruction the students become aware in task 7 of a need for extending their knowledge in the context of decision making about packages: a need of knowledge about criteria-related properties of packages and packaging materials in order to be better able to compare packaging alternatives on the environmental criteria. In the reconstruction of the whole-class discussion in task 7 elements of the whole-class discussion in task 9 have been inserted, as far as these fragments relate to what should have been discussed in this earlier task. The additional interventions (in italics) have mainly been limited to possible contributions of the teacher in the spirit of the scenario. These contributions concern instances of making explicit that a question for further investigation has emerged, instances of guiding the whole-class discussion in such a way that both alternatives are being compared on both environmental criteria, and instances of stressing the decision-making context. During the whole-class discussions that actually took place, the lines of questioning suggested in the scenario have only been partly used by the teacher. Therefore the reconstruction remains incomplete: on a number of points the students' explicit reactions remain to be guessed. These reactions thus have been 'filled in' in general terms such as 'disagreeing/not knowing', based on the observations of the interaction between students during their small-group work on the tasks concerned. For that reason the intended questions for further investigation concerning the comparison of packaging alternatives on the environmental criterion of pollution cannot be based on students' reactions. This part of the reconstruction therefore offers too slender an empirical basis for a proper judgement of the didactical structure. Still, this reconstructed outcome of task 7 gives a reasonably satisfactory view on its potential as one of the key tasks representing the problem-posing character of the didactical structure. Moreover, in this reconstruction tasks 8 and 9 connect rather well to task 7.

Conclusion – The design/research question for this second phase in the didactical structure cannot yet be answered in a fully affirmative way. However, it has been argued above that the cause of the teaching/learning process getting off-track from task 6 onwards does not seem to lie in an inadequate design of the sequence of tasks, but rather points at an inadequate teacher preparation. The scenario is quite explicit about the tasks' purposes, expected outcomes and lines of questioning to be taken by the teacher to arrive at those outcomes. However, it appears that for the key tasks representing the problem-posing character of the didactical structure a more extensive discussion with the teacher is needed, focusing on the lines of questioning necessary to turn the students' initial agreement about the comparison of packaging alternatives on the environmental criteria into instances of disagreement or not-knowing. Additional points of discussion would be of a more technical character: making a fluent transition from one task to the next, making explicit emerged questions for further investigation, structuring the discussion about comparing both packaging alternatives on both environmental criteria, and stressing the decision-making context.

The conclusion can be that this elaboration of the question phase in the didactical structure is now *potentially* 'good enough' for practical purposes. Potentially, because the empirical support from the classroom trial consists of a *reconstruction* of the teaching/learning process along the lines set out in the scenario – and, moreover, a reconstruction that in some aspects is still incomplete. This mainly concerns the expected outcomes of task 7 with respect to a question for further investigation concerning pollution through dumping and burning packaging materials.

Methodological reflection

In this section a method of *reconstruction* has been used to retrospectively 'make the best out of what actually happened in classroom practice'. In which circumstances would making a reconstruction be useful? And which rules have to be followed in the making of such a reconstruction? A reflection …

The method of *reconstruction* seems to be useful in those cases where everything or at least quite a lot of what according to the scenario was supposed to happen in classroom practice did actually happen, but happened in the wrong order. That is, using this method can contribute to providing an empirical base to judge the adequacy of the didactical structure in case of a mismatch between scenario and teaching practice as far as the *sequence of teacher interventions* is concerned. In making a reconstruction, first the teacher's interventions are sequenced according to what the scenario indicates as being the *intended sequence*, together with the students' reactions. Besides, the teacher's interventions are completed according to what the scenario indicates as being the *intended content*. Such a reconstruction only offers partial empirical support for the didactical structure, if it results in a 'reasonably fluent' storyline: something that *could have happened* in the classroom. This is not to say that such a 'reasonably fluent' storyline automatically supports the didactical structure. The conclusion, of course, could also be that what *could* have happened in the classroom does not meet the scenario's expectations.

In making such a reconstruction a number of rules seem to have been developed and followed. These *reconstruction rules* are made explicit below. A general overlying principle in applying these rules is that a reconstruction should be limited as much as possible to rearranging of what actually happened.

- The *scenario* provides the starting point for the sequencing and/or completing of the teacher's interventions. If this is not the case, the reconstruction cannot contribute to providing empirical support for the didactical structure – as is the intention of making the reconstruction.
- The *students' reactions* remain attached to the (replaced and completed) teacher's interventions, and remain unaltered – maybe with the exception of an occasional supplementary, but very plausible remark. Or, in other words: the *coherence* between the teacher's interventions and the students' reactions is maintained. If this is not the case, the reconstruction changes into a construction which is no longer based on the classroom interaction between teacher and students that did take place. Such a construction, then, is just an assumption to be tested, and so cannot contribute to providing empirical support for the didactical structure.
- The used classroom fragments (so, the collection of related teacher interventions and students' reactions) are closely connected in *time*, e.g., within a lesson. If this is not the case, the students' reactions to a teacher intervention that has been moved forward in the reconstruction might be coloured by their intermediate experiences. For the same reason, no interfering information may become available to students in between the used classroom fragments – even if they are closely connected in time – unless that information is sensibly integrated into the reconstruction. Certain classroom fragments can therefore only be left out of the reconstruction if they are clearly superfluous and have a negligible influence on the rest of the teaching/ learning process.

6.5 The investigation phase: extending knowledge

The design/research question to be answered in this section about the trial of the unit's investigation phase as described in chapter 4 (section 4.4), given its purpose, is:

- *Does this teaching/learning activity make students extend their knowledge, guided by their questions for further investigation?*

Classroom trial

During the trial of the modified version of the unit, the three tasks in the investigation phase went roughly as planned and expected in the scenario – with one important exception related to the students' perception of pollution through dumping and burning of packaging materials.

Task 10: Research – The teacher starts with introducing the research, referring to the questions for further investigation formulated at the end of the previous phase. The

audio-visual reference materials are watched by the class as a whole, followed by small-group work during which the written reference materials are being used to assess the criteria-related properties of packages and packaging materials. The students are working rather concentrated. The written reference materials are being used in a somewhat superficial way: as soon as an answer has been found it is written down in the table. Further reading of additional information seems to be rare.

The whole-class discussion about the students' answers results in a completed table roughly as expected in the scenario. This means that – for the time being – the students accept the information provided by the reference materials as being correct.

Task 11: Summary – The collected information about the criteria-related properties of packages and packaging materials is further structured in a whole-class discussion by 'scoring' each material on both environmental criteria. Part of this discussion is reproduced in figure 6.8. The introduction of this task by the teacher is limited to summarising collected information, without any reference to what this summarising might be useful for: using this summarised information in decision-making situations in the next phase of the unit. In these situations packaging alternatives are going to be compared on both environmental criteria (as has been done earlier in the unit's second phase). So, it would be better to have the collected information structured accordingly.

T Now let's try to summarise in task 11 what we now know about those five packaging materials ... if we're able to score them on the two environmental criteria: depletion of raw materials and pollution through dumping and burning. Then we have found an answer to the research questions. What about paper and carton? Who's got an idea? Is there a problem concerning depletion of raw materials?

S_1 No.

S_2 Because they're being replanted.

T No, because the raw material is renewable and the resource stays at roughly the same level. Agreed? And what about pollution through dumping or burning [S_3]?

S_3 I don't know.

S_4 No.

T No. Why not?

S_4 Because it's being recycled.

T But that's only six percent, as we just have seen. So a large part is being dumped or burned. And does that represent a problem? What did we just see?

S_5 No.

T No. It does scarcely contain harmful substances ... a little bit of chlorine, as we just have seen. But in this case that doesn't represent a problem really.

Figure 6.8 – Whole-class discussion: structuring collected information about a packaging material.

In the course of the whole-class discussion the students appear to have some difficulty to select the essential information put forward and to complete the table. After finishing this task, some students express their amazement with respect to the outcomes concerning pollution through dumping and burning of packaging materials.

This reaction is reproduced in figure 6.9. In retrospect, this is a first indication that students are not convinced of pollution through dumping and burning of packaging waste being 'no big problem'.

These doubts about the information in the reference materials being correct will be put forward by the students far more prominently in the unit's next phase in which the students are asked to apply this structured practical knowledge in decision-making situations: burning releases CO_2 (and the like) and that means pollution, burning plastic causes smoke and smell and that represents harmful, cancer-inducing substances …

S_1 So, concerning pollution nothing [not any packaging material] presents a problem?
T No, nothing presents a problem regarding dumping or ...
S_2 Except for plastic ...
T ... burning. Except that PVC, yes.
S_2 Yes.
T But not that plastic used for packing.

Figure 6.9 – Whole-class discussion: a first indication of students' doubts about the information in the reference materials being correct.

Task 12: Additional research – The students seem to appreciate the practical work and interviews as a welcome variation in working methods. Reporting about their activities to the class does not seem to cause any anxiety or stress. The students show their involvement by asking for clarifications about what has been done by others and the results, and by commenting on – in their view – poor presentations of the research question and connected conclusion. There are even instances in which the students themselves completely take over the questioning role of the teacher. This could be seen as an indication of a continuing involvement of the students in the teaching/learning process, as quite often oral reporting to the class doesn't trigger much of this kind of interaction.

Evaluation

The above-given description and illustration of classroom practice will first be discussed in the light of the design/research question about the unit's investigation phase. In conclusion, an answer to the question at hand will be given, as well as some ideas about the necessary fine-tuning of the scenario and modification of the student materials.

Discussion – The students are clearly able to extend their specific issue knowledge on the basis of the questions for further investigation and to structure this knowledge in such a way that it can easily be applied in decision-making situations. This seems to be quite some improvement compared to what did happen during the first trial. The shift away from a labour-dividing approach therefore seems to have been a sensible one. This time all students have been working on extending their knowl-

edge about all criteria-related properties of all (five) packaging materials. A problem might still be that relevant details are being overlooked, and therefore not addressed in the whole-class discussion.

However, something seems to be seriously wrong in this phase of the unit: to the students the credibility of the information about pollution in the reference materials is questionable. At this point in the unit there is only a vague indication that this is the case. The problem comes out into the open during the unit's next phase when students are presenting their argued points of view about a self-chosen decision-making situation in task 16, as shown in the whole-class discussion of figure 6.10.

T [...] Now, about this pollution. You're saying: plastic pollutes.
S_1 Yes.
T Could you explain that, because this is returning time and again. In the table of task 11 we did say: plastic doesn't pollute, as long as it isn't PVC. And now I quite often hear, also in other reports: plastic pollutes.
S_2 Yes, it says there that it doesn't pollute. But to me it seems that when you burn it, it gives off an unbelievable stink ...
S_3 Cancer inducing.
S_2 Pollution. If you burn it [inaudible] there must be something wrong.
S^s [simultaneous inaudible reactions]
T Ok. We have concluded something in task 11 ... we've read that in the reference materials. Now, we're a bit amazed at that ... we have some difficulty in accepting that plastic doesn't pollute. Because you say: if I take a piece of plastic and put it on fire here in the classroom, then after three days I can still smell it – so, it has to cause pollution.
Is that so? Does everyone agree?
S^s Yes.
T Yes? Everyone agrees? Well, I don't.
S^s Well, we do.
T Because how is this burning in an incinerator being done? It's being burned at a very high temperature. And at this high temperature it isn't that ... look, if you burn a newspaper here, you also get a lot of soot. But if you burn it at the right temperature you don't get this pollution ... not those polluting substances. What you do get – and that has already been noted earlier ...
S_3 PVC
T It contributes to – and this goes for any burning – the greenhouse effect.
S^s Yes.
T CO_2. But that's a different kind of pollution from what he [S_2] is indicating. He's talking about messy stuff getting into the air.
S_2 No, we're talking about pollution in general. It gets into the air ... stink and all.
T And I say: there's no stink if you burn it correctly. There is if you're putting a match to it, but not if you burn it at a high temperature.
S_2 I don't know, I've never been near such an incinerator.
T Now what happens ... we have concluded something from the reference materials, and all of you are saying something like: would that be right, well ok, that's like it is. And then the next lessons you're saying: it isn't like that.
S_2 Yes. I think it's strange that if you burn something it doesn't pollute. Seems illogical to me [inaudible].
S_3 These reference materials could be wrong, couldn't they?
S_2 Yes.
T So, to summarise ... the question is: are those reference materials correct? Because you can't imagine that's the case.

S_2 Yes.
T That could be, but ... it's not very probable. Ok, let's continue with the next report.

Figure 6.10 – Whole-class discussion: students' clearly expressed doubts about information in the reference materials being correct.

After this preview of what happened somewhat later in the unit's application phase, it can now be said that the students do indeed extend their specific issue knowledge during the investigation phase of the unit, but not quite as intended and expected in the scenario as far as the *character* of this knowledge is concerned. The information presented in the reference materials that packaging materials are not very harmful when dumped or burned is largely correct. But the way in which this information is presented apparently does not connect to the students' knowledge gathered through media reports that dumping and burning waste causes pollution and therefore is detrimental to the environment. The reference materials do not acknowledge that dumping and burning of *waste* indeed is harmful, and do not pay any attention to the difference between *waste* and *packaging waste*. This means that the reference materials do not connect to the students' everyday life practical knowledge about pollution through dumping and burning waste. Another problem consists of the CO_2 mentioned by the students as representing pollution. Dealing with this aspect would considerably increase the complexity of the unit and the amount of information to be processed. This does not seem to be very desirable.

Conclusion – There are some doubts about a clearly positive answer to the design/ research question for this third phase of the didactical structure. However, it is most likely that the answer to this question would be affirmative after some fine-tuning of the scenario and modification of the student materials related to the deficiencies outlined above. The conclusion could then be that this elaboration of the investigation phase of the didactical structure would indeed be 'good enough' for practical purposes (teaching practice), provided that the following ideas are going to be incorporated in the scenario and the reference materials to be used by the students.

The scenario and the reference materials in one way or another should connect to the students' knowledge about pollution. In order to make such a connection the reference materials and the whole-class discussion have to address the question why dumping and (especially) burning of packaging waste does not (or not very much) contribute to the familiar and acknowledged pollution caused by dumping and burning waste in general. Dealing with the CO_2 aspect of burning specific packaging materials (paper/carton and plastic) seems to be something better to be dealt with in a follow-up unit about the energy issue. In such a unit burning waste could be treated in the context of using waste as a fuel. That is, as an alternative to burning fossil fuels, e.g., to generate electricity. This would then be an illustration of a reconsideration of earlier made choices in the light of new information. However, it remains an open question whether the students will accept such a reference to a follow-up unit.

A remaining point of concern is the still somewhat superficial way the students deal with the information provided by the written reference materials. A solution to this problem cannot easily be found. One idea is to replace the written reference materials by an electronic data base organised by a search program using the criteria-related properties of packaging materials as primary and the different packaging materials as secondary access codes. In this format all of the information appearing on the screen might more easily be acknowledged by the students as being relevant for finding an answer to the specific part of their questions for further investigation.

6.6 The application phase: using extended knowledge

The question to be answered in this section about the trial of the unit's application phase as described in chapter 4 (section 4.5), given its purpose, is:

- *Does this teaching/learning activity make students use their extended knowledge for arriving at an argued point of view in decision-making situations?*

Classroom trial

Based on what actually happened in classroom practice during the trial of the modified version of the unit, some serious flaws in the scenario were identified. These flaws concern a lack of clarity regarding the development of *standards* for the contents and presentation of an argued point of view, with a stagnation of the teaching/learning process as an understandable but nevertheless rather disappointing result.

Task 13: Decision-making situation: carton/bottle – The teacher starts off by looking back at the teaching/learning process so far, as reproduced in figure 6.11. This transition from the investigation to the application phase does not go very smoothly, but anyway the teacher recognises the importance of making explicit the global teaching/learning process at this point and is trying to engage the students in doing so. The teacher's questioning maybe a bit too quickly turns into lecturing, but his reference to the questions for further investigation is quite appropriate. Also his introduction of task 13 makes sense, although this introduction is referring more to what *should* have happened in the second phase (formulating questions for further investigation in consequence of an established knowledge need when comparing packaging alternatives on the two environmental criteria) and not to what has actually happened in classroom practice at that time. Given these conditions, what the teacher is doing here is probably the best he can do. Contrary to what did happen during the first trial, the students now display no 'reluctance' in starting off on this application phase in the unit. This might be seen as an indication of an improved awareness of the intended global teaching/learning process.

T In the previous lesson, the reporting session, we concluded activity three. This means ... now what did we

actually do in that activity ... in the previous four lessons?
S_1 Well eh ... research ... about raw materials ...
S_2 Finding out about eh ... materials, which raw materials and whether or not those are renewable.
T And why did we do that? Why did we spend four lessons on that?
S_3 [inaudible]
T And what did you have to do, and why?
S_3 We have looked at what happens with raw materials ... and what happens with waste ...
T Do you still remember ... at the end of activity two we have formulated research questions. And those research questions ... why did we formulate them? Because there were a number of things about packages we didn't know yet in making a choice ... why would you buy milk in a bottle or a carton. We did a task on that ... can you still remember that? Then we said ... one thought this, another thought that ... a lot of things we didn't know yet. Those we did formulate as research questions. And in activity three we did investigate those questions. How did we do that? We have watched a videotape, we have searched for information in reference materials and summarised it in a table, we have performed experiments and reported about the results to each other. [...] We have found answers to those questions. So now, if we have to make that choice again, we can use the information we have found. Well, that's what we're going to do in the next activity. We're now ...
S_4 We've already done that one.
T He [S_4] says: we've already done that task [task 13]. That's right ... well noticed. You can buy milk in a carton and in a bottle. You can choose between the two ... you can argue your choice. We did this task in the beginning. And then we found out there were a lot of things we didn't know yet. We didn't know whether or not we could throw in this [shows carton] with the waste paper. Well, in the meantime with the help of the reference materials and the experiments we have found answers to those questions. So, now we know a lot more. Therefore we're going to repeat this task ... with the help of the knowledge we now have we're going to see if we're better able to make a choice if we would be willing to contribute to a better environment. So, the task is exactly the same indeed. However, now we have more knowledge, so we'll probably be able to perform better on this task.

Figure 6.11 – Whole-class discussion: reflection on the teaching/learning process.

The small-group work on task 13 presents no problem. However, the ensuing whole-class discussion reproduced in figure 6.12 does not at all go as planned in the scenario. First of all the teacher starts asking about the students' final decision, instead of their comparisons of the alternatives on the environmental criteria. This necessitates further questioning, which could have been prevented and would have caused a less lengthy and therefore more clear and structured discussion. A second factor complicating the discussion is the earlier mentioned emergence of the students' doubts about the information about pollution in the reference materials being correct. It might be that these distractions result in the fact that making a comparison-on-criteria-based decision is not addressed in the discussion.

T In task 13 you have been asked for the second time to look at the choice between a carton and a bottle. Which of those two would you choose if you pay attention to the two environmental criteria [S_1]?
S_1 The bottle.
T And why do you choose a bottle? Concerning depletion ...
S_1 Well, it can be recycled. So you don't have to use new raw materials over and over.
T Yes. So, the bottle ... that saves raw materials.
S^s Yes.
S_2 And a carton ...

T But what about the carton with respect to raw materials?
S_1 That's eh ... carton and plastic mixed up. According to me it can be recycled, but then it is not used for milk cartons any more.
T No ...
S_1 Then it's used for garbage bags or something like that.
T Yes, because what happens with a carton? It's not being recycled. Can you thrown it in with the waste paper?
S_3 No, there's plastic in it.
T So, it's being dumped or burned. Then what about depletion of raw materials?
S_4 Yes, there's depletion.
T But what about wood? Wood is the raw material for paper. Is that running out?
S_5 No ... not wood. But plastic.
T How comes?
S_5 Wood's coming from trees, man. Those you can replant.
S_6 But plastic, that's oil and that gets ...
T But those are two different things, aren't they?
S_6 But if paper can be recycled, then you're going to recycle it ... even if there are enough trees in the world.
S_7 But only the carton cannot, because there's plastic in it ... just carton is not so much of a problem.
T Ok. Now we're being clear about this. Just the carton is not so much of a problem, because the raw material is not being depleted ... trees will grow again. But there's plastic to it. And plastic comes from which raw material?
S^s Oil.
T Oil. And oil is a non-renewable raw material.
S_5 Yes, that's what I just said.
T Ok. So concerning depletion she [S_1] says: I choose a bottle. Is there anyone with a choice for the carton on this environmental criterion of depletion? ... No? Then you can also compare those two on the environmental criterion of pollution. Who's got a choice there [S_8]?
S_8 I've got: plastic does when it's being burned, and paper is being recycled ...
T So, regarding pollution you choose a carton?
S_8 Yes.
T This here [shows bottle] ... can't be refilled any more after six times. Is it then burned?
S_9 No, they're being ... recycled.
T Recycled.
S_1 For phones and the like.
T Yes ... or garden poles. So, these are refilled, and when they're not refillable any more they're being recycled into other stuff. So, regarding pollution ... does this [shows bottle] contribute to pollution?
S^s No/not much, really.
T Not much ... almost not, isn't it? And what about the carton? Does this [shows carton] contribute to pollution?
S_2 Yes.
T In what way?
S_3 In burning or dumping.
T This carton consists of two materials: paper and plastic. When we burn paper, does that contribute to pollution?
S_4 Yes.
T When we dump or burn this, is that detrimental to the environment regarding pollution? Does burning paper cause the release of harmful substances?
S_5 No, not with paper ... but it does with plastic.
T Yes, but now we're talking about two things at the same time, so let's try to keep those apart. Dumping or burning paper, is that harmful?
S^s No/Yes/Of course.
S_6 There's chlorine in it, isn't it?
T Of course, you say. Explain that.

S_7 Burning it gives off smoke. And smoke pollutes the environment, whether it contains harmful substances or not. And acid rain is just bad.
T Ok. In that sense it contributes to pollution ... but not with respect to harmful substances. And when we dump it?
S_8 No.
T So, in general paper doesn't contribute to pollution, except when it's burned ... because then smoke is released which contributes to acid rain. But not if you dump it. And what about plastic?
S_9 That does.
T Does plastic contribute to pollution when dumped or burned?
S_1 Yes.
T Why?
S_1 Burning plastic causes toxic substances in the air.
T Which then?
S_2 Not if there's no PVC in it.
T Is there PVC in such a milk carton?
S_2 No.
S_1 Ah.
T Ok. So what have we got regarding pollution by the carton ... that turns out to be not that bad. But now let's go back to the bottle for a moment.
Does this bottle not at all contribute to pollution? When you return it for refilling, are they then just going to poor milk into it at the factory?
S_3 They have to clean it first.
T And does that contribute to pollution?
S^s Yes/cleaning stuff.
T So, such a bottle does contribute to pollution through cleaning. Now if we take all this into account ... What can we say about depletion? Well, depletion here [shows carton] is more than here [shows bottle]. When we look at pollution, what strikes you? What's polluting about this [shows bottle]?
S_4 Cleaning.
T Cleaning stuff. And what's polluting about this [shows carton]?
S_5 The air.
T Yes, a bit in burning. So, with the bottle we have a disadvantage concerning cleaning, and with the carton a disadvantage concerning depletion. [...] Now, what did we do: comparing on depletion ... both packages, and comparing on pollution ... again both packages. And one of them is scoring low on pollution, and the other one is scoring low on depletion. Ok. That's what we've done. And that's something we're able to do now, as we've been extending our knowledge in the previous lessons with the help of the reference materials, the experiments et cetera. We have found an answer to our research questions. So now we are indeed able to compare on the two environmental criteria.

Figure 6.12 – Whole-class discussion: decision making about packaging alternatives.

In the whole-class discussion it appears that the students' qualifications of the bottle and the carton on the two environmental criteria differ from the qualifications the teacher has in mind. The teacher's questioning is mainly directed at convincing the students that his qualifications are correct. The discussion ends when the teacher seems to have succeeded in this. The emphasis therefore is on the qualifications of the packaging alternatives on the environmental criteria being complete and correct. Using these qualifications for comparing the alternatives on each of the environmental criteria is addressed to some extent, resulting in – but here it is getting a bit diffuse – a choice per criterion. How to arrive at a decision about the best alternative based on these comparisons is not being addressed. Therefore, the students are not

presented with a clear example of an argued point of view, which would have been the task's purpose as – not all too explicitly – expressed in the scenario. This will have its repercussions in task 15 and 16 in which students are asked to replicate the decision-making process in a different, self-chosen situation. The students will have to do this without the guidance of a clear example of an argued point of view.

The task is concluded by a short discussion about the dynamic character of decision making. The students are able to mention some future developments that would necessitate a reconsideration of the choice being made: recyclability of laminates (carton) and less aggressive cleaning agents (bottle).

Task 14: Weighting – The transition from task 13 to task 14 is not very fluent. This comes as no surprise as task 14 asks for a reconsideration of the choice made in task 13 when other than environmental criteria are also taken into account. But in task 13 no choice has been made, thus making this reconsideration rather difficult. What happens is that students appear to be able to mention additional criteria, and that's about it. The idea of necessary weighting of comparisons on different criteria does not really come forward explicitly.

Task 15: Choosing packages – The task is introduced without any reference to the comparable task 13. The teacher points at the reference materials for information about packages and packaging materials, where a reference to the summarised information in the table of task 11 would have been more appropriate. Furthermore, the teacher extends the task by suggesting that students not only compare the alternatives on the two environmental criteria, but also on self-chosen other criteria – which was not included in the task according to the scenario. The small-group work on this task proceeds quite smoothly.

Task 16: Reporting – The presentation of the argued points of view in the decision-making situations chosen by the students in task 15 is quite a time-consuming affair, as the students have been working in pairs and all groups are asked to deliver their presentation. In most cases the students are trying to construct an argued point of view by comparing their self-chosen packaging alternatives on environmental and other criteria. An example is reproduced in figure 6.13. However, the contents and presentation of these argued points of view both leave to be desired. This is quite understandable, as an example of an argued point of view did not come forward in task 13 and identifying the points to pay attention to when putting forward such an argued point of view as well as possible is the purpose of task 16 itself. The teacher's questions mainly (have to) deal with the contents of the presentations: have the alternatives been compared on both environmental criteria in a complete and correct way? Or, in other words: the teacher's questions are again focused – as in task 13 – on getting the qualifications of the alternatives on the environmental criteria right. After a number of presentations the students are also doing this themselves. This can be considered as a positive development. However, the teacher does not give enough feedback on the students' presentation of their argued points of

view. Explicit feedback on one presentation might have led to an improvement of the subsequent presentations in terms of the identified alternatives and criteria, a systematic comparison of these alternatives on these criteria and a weighting of these comparisons resulting in a decision. As one of the students after a number of presentations remarks: all these reports are just 'more and more of the same'. This points at a basic problem in this task: the teaching/learning process seems to be at a standstill. This is aggravated by a recurrent emergence of disagreement between the teacher and some students about the contribution of packaging materials to pollution through dumping and burning as mentioned earlier. The effort aimed at 'getting the qualifications of the alternatives on the criteria right' is detrimental to the task's aim of establishing the requirements for a *clear* presentation of an argued point of view. The effort of making these requirements explicit in the conclusion of this task therefore does not yield very much, as becomes apparent from the whole-class discussion reproduced in figure 6.14.

S_1 We have the difference between egg boxes of plastic and carton. Well ... depletion: those carton boxes are the best of course, because they're made of renewable wood ... trees are replanted. And you can also recycle them rather well, because it's [inaudible]. And the plastic ones can be recycled, but then chlorine gets into the water. And the raw materials are non-renewable, this oil.

S_2 Then pollution. The carton doesn't contribute to pollution. And that plastic then gives off chlorine ... which is polluting the ground water. Finally the price: a plastic box is more expensive than a carton box, because there is eh ... more work for recycling it [inaudible].

T They [S_1 and S_2] have made a choice between eggs packed in plastic or carton. And they have given an overview of their arguments. Well, who's got some comments?

S_3 That carton box is always made of recycled paper, isn't it?

S_1 Well, what does that matter?

T A carton box is made of recycled paper, you say [S_3]. So, what are you trying to get across?

S_3 The raw material thus is just ordinary paper, really ... waste paper.

T Waste paper. And that's what egg boxes ... egg boxes are not being made out of new trees, is what you're saying ... but out of waste paper.

S_3 Yes.

S_1 That can be recycled once again, isn't it?

T More comments? ... I myself have got a question. According to me we did conclude that plastic does not pollute as long as it isn't PVC. And you are saying: yes, plastic pollutes.

S_1 Yes, but when you clean it, all this chlorine gets into the environment.

T Then where does that chlorine come from?

S_1 From those toxic ... what's that called ... from those substances with which you clean it ... cleaning stuff.

T Ah, you mean when cleaning ... cleaning agents.
But would they refill plastic just like a milk bottle? Or will they recycle it? What's the difference between those two?

S_4 Re-melting.

T Recycling is re-melting and using it again. And refilling is cleaning ...

S_1 But then, before recycling, you also have to clean it, haven't you?

T And so you say: they're going to refill ... According to me, they don't do that with these plastic boxes.
Any other comments?
What did you think of their argumentation? Who could say something about that?

S_5 I thought is was quite ok.

T You thought the arguments were fine ... well structured, well compared both of them?
S^s Yes.

Figure 6.13 – Whole-class discussion: students reporting and discussing an argued point of view about a self-chosen decision-making situation.

T In the previous lessons you all gave your reports. You were supposed to present an argued point of view about the choice between two packaging alternatives. Let's go back to that: who can tell me what requirements an argued point of view should meet [S_1]?
S_1 Yes, well eh ... depletion and pollution.
T And what do you call that, those two?
S_1 Environmental criteria.
T Environmental criteria. So, you have to compare the two alternatives on those environmental criteria.
S_1 And on price and quality.
T And also on other criteria you find important, such as price and quality. On those you compare them, yes. And then?
S_1 Then nothing.
T Sure is, there's something else. What else do you need before being able to present an argued point of view? ... What have we been doing these past weeks? What did we do [S_2]?
S_2 Well, about depletion and pollution.
T Sure, those are the two environmental criteria. That's what he [S_1] just said. But what else did we do [S_3]?
S_3 We did investigate what's better for the environment ... this recycling and eh, yes ...
S_4 [inaudible]
T Before you can make a choice – we've been dealing with that bottle and carton – what do you need besides those two environmental criteria on which you compare? ... Why, for example, do you need those reference materials?
S_2 For finding the answers.
T But what kind of answers? To what kind of questions?
S_5 That you don't know.
T Things you don't know. Yes? So, in other words: before being able to present an argued point of view you have to ...
S_6 Investigate.
T Yes, you have to have knowledge. Knowledge about the properties of those different packaging materials. You have to know the properties of those laminates, or of tin-plated steel or of who knows what – before you can say what you choose and why. With that knowledge you can compare them correctly on those environmental criteria.

Figure 6.14 – Whole-class discussion: establishing the requirements for a clear presentation of an argued point of view.

Evaluation

In the above-given description and illustration of classroom practice mention has been made of a stagnating and therefore still dissatisfactory teaching/learning process during the tasks 13 and 16. In order to identify what exactly went wrong here, a closer look at what happened in classroom practice seems to be necessary. This will be done by giving an *interpretation and reformulation* of the students' written and oral utterances on both tasks mentioned, leading up to some ideas about a far more sharply defined purpose of both tasks in terms of developing a *content*

standard and a *presentation standard* for an argued point of view and their implications for the necessary revision of the scenario. This will be followed by a *reflection* on the method of interpretation and reformulation.

Discussion – The earlier given design/research question for the application phase of the unit asks whether this teaching/learning activity makes students use their extended knowledge for arriving at an argued point of view in decision-making situations. If the question is formulated in this way, the above-given empirical data suggest that it must be answered affirmatively. For students do indeed use their extended knowledge for arriving at a to some extent argued point of view in decision-making situations about packages. Nevertheless, these results have given cause to be dissatisfied with the course of the teaching/learning process during tasks 13 and 16. This dissatisfaction originates from something the design/research question does not address: the *quality* of both the content and the presentation of an argued point of view put forward by the students. This has only gradually become clear during the reflection on this classroom trial, thus pointing at some major deficiencies in the scenario. In retrospect, a far more sharply defined purpose of tasks 13 and 16 would be the following: developing and making explicit a *content standard* and a *presentation standard* for an argued point of view, respectively. The design/research question to be answered for the application phase of the unit would then be whether or not these standards have been established. The identified stagnation of the teaching/learning process during the classroom trial points at a negative answer to such a more specific, retrospectively formulated, design/research question – which should come as no surprise. Now, what can be said about classroom practice during the trial in the light of this adjusted aim of the unit's application phase?

It has already been noticed that the connection between knowledge need, extension and application of knowledge now is far more stronger than in the unit's first version. This is because of an early summoning of this knowledge need in the context of decision making about packages. Now also the environmental criteria are clear from the start, so that the students' decision making should be less complex and confusing. It seems that this is indeed the case. Therefore, some opportunity for introducing and making explicit a content standard and a presentation standard for an argued point of view has been created. What students are putting forward when discussing task 13 and when reporting in task 16 does seem to provide enough starting points to do so – and certainly far more than the students' reactions to the constructed, artificial points of view prominent in the unit's first version. Below, the character of both standards will be elaborated under the heading of *interpretation and reformulation*. This is followed by a closer look at the teaching/learning process, which shows that development and explicitation of both standards would have been possible.

An annoying complication during this phase is the fact that only now it has fully become clear that the planned progress of the students' specific issue knowledge in the unit's preceding investigation phase has not been realised to a sufficient degree.

The problematic discrepancy between the students' everyday life knowledge about pollution and the information in the reference materials has to be solved first in the way roughly outlined in section 6.5. Then the teacher will be able to concentrate on having the students make progress concerning the contents and presentation of their argued point of view.

The preliminary conclusion must be that the elaboration of the application phase in the didactical structure is not yet 'good enough' for practical purposes. The sequence of tasks seems quite fine, but the scenario definitely is not. With a view to the identified stagnation of the teaching/learning process, the scenario needs somewhat more than a mere fine-tuning. A considerable revision is needed, so that the scenario far more clearly shows the tasks' purposes of establishing a content standard and a presentation standard, the character of these standards and the guidance needed for the students to arrive at those standards. The question can therefore be whether something can be learned from the classroom trial concerning such a scenario revision, despite the identified unfavourable conditions.

Interpretation and reformulation

In order to assess the possibilities of developing and making explicit a content standard and a presentation standard for an argued point of view, one has to consider what the students wrote down in their workbook concerning task 13, as this is the starting point for developing both standards. This, however, raises another, and more fundamental question: how to properly interpret what students are writing down or saying (Klaassen & Lijnse, 1996)? Addressing this question of interpretation almost automatically leads to a characterisation of both a content and a presentation standard.

The structure of task 13 stimulates students to make an argued choice by taking the following three consecutive steps: establishing relevant alternatives and relevant criteria, comparing these alternatives on these criteria, and choosing an alternative by weighting of the comparisons made. This series of steps is the starting point for characterising and, if necessary, criticising the students' argued points of view.

Characterising a student's argued point of view means interpreting his or her factual written or oral utterances along the lines of the above mentioned three steps. Or, put differently, it is only if these three elements can be plausibly read into a student's response, that it makes sense to say that the student has made a choice. This implies that the student's utterances must, if necessary, be so reworded and/or rearranged that they result in a coherent and sensible argumentation which makes the student's final choice understandable. Such a *reformulation* can be seen as a reproduction of what the student, according to the reader or listener, intends to express with his/her factual utterances. Such a reformulation then encompasses the alternatives, the criteria on which these alternatives have been compared, the comparison of the alternatives on each of the criteria, the ensuing comparison-based choices per criterion, the weighting (either trivial or not) of these choices and the weighting-based final choice. This reformulation forms the basis for criticising, if necessary, the *content* and/or the *presentation* of the student's argued point of view.

In the context of the unit, this criticising is not aimed at any assessment of the students. On the contrary, it aims at progress in the teaching/learning process with respect to the content and presentation of an argued point of view put forward by them.

Criticism of the *content* of an argued point of view results from comparing the reformulation with a *content standard*: a 'perfect' reasoning with respect to completeness and relevance of alternatives and criteria, and with respect to completeness and correctness of the alternatives' qualifications in the comparisons per criterion. It cannot be a criticism of the content, however, that the choice is not what it should have been, given the student's own comparison-based choices per criterion and weighting of these comparisons. For such a criticism would imply that the reformulation of the student's argued point of view does not represent a coherent and sensible argumentation. In such a case one should rather question one's reformulation of the student's argumentation.

Criticism of the *presentation* of an argued point of view results from comparing the student's factual utterances with a *presentation standard*: a clear reproduction of the alternatives and criteria, a systematic reproduction of the comparison of the alternatives on the criteria, and an explicit reproduction of the choices per criterion, the weighting of these choices and the final choice. As the reformulation is put in this format, criticism of the presentation of the argued point of view can result from comparing the student's factual utterances with this reformulation.

Content standard

The more sharply defined new purpose of task 13 would be to develop and make explicit a *content standard* for an argued point of view. In order to come to see what could be expected in classroom practice and therefore should be addressed in the scenario's revision, the students' argumentations in their workbooks concerning the bottle/carton decision-making situation of task 13 have been reformulated and criticised with respect to their contents. The results will be presented below. However, criticism of the content of an argued point of view not only requires a reformulation, but also and first of all a content standard. Such a standard has been described as a 'perfect' reasoning related to the decision-making situation at hand. What does such a 'perfect' reasoning look like, given the unit's contents? And what can be expected of the students in this respect, given the way these contents have been dealt with in classroom practice?

Content standard – A 'perfect' reasoning, given the unit's contents, for the bottle/carton decision-making situation in task 13 can be taken from the scenario, where it describes (the example of) the intended and expected argued point of view. This part of the scenario is reproduced in figure 6.15. For the sake of clarity, this 'perfect reasoning' has been converted into the more schematic reproduction of figure 6.16 by using the format of the task concerned in the students' workbook.

It is not to be expected that the students' written argumentation as a result of their small-group work on task 13 will comply with this content standard. In the

investigation phase of the unit there is a non-resolved discrepancy between the students' everyday life perception of pollution through dumping and burning waste and the information provided in the reference materials. It therefore can be expected that some students will qualify the carton on pollution as being harmful. Moreover, water pollution by aggressive cleaning agents has only been addressed in the audio-visual information and has not been further discussed in tasks 10 to 12. It therefore can be expected that some students will qualify the bottle on pollution as refilling/ recycling non-harmful, because there is no pollution either through cleaning (because this is not being recognised) or through dumping/burning (because that is not applicable).

- With respect to the contribution to depletion of raw materials for the production of packages the plastic bottle is scoring better on this criterion because of refilling and ultimately recycling of plastic which implies no contribution to depletion of the raw material oil for plastic, set out against dumping/ burning of the paper/plastic laminate of the carton which implies a contribution to depletion of the raw material oil for plastic. In the case of the carton depletion of the raw material wood for paper is out of order because of its renewability.
- With respect to the contribution to pollution through dumping/burning packaging waste the bottle and the carton are at a draw: no such contribution by the bottle because of refilling/recycling; and no such contribution by the carton because the paper and plastic are both non-harmful when dumped/burned. However, the bottle causes water pollution through cleaning before refilling, so that the carton is scoring better on this criterion.
- So, it seems that the choice between the bottle and carton depends on what is thought to be more important: depletion of raw materials in the long run, or water pollution on short term.

Figure 6.15 – Scenario: a 'perfect' reasoning in the bottle/carton decision-making situation of task 13, given the unit's contents.

product	milk
alternatives	bottle (plastic), carton (paper/plastic laminate)
criteria	depletion, pollution

criterion	comparison		choice
	bottle (plastic)	carton (paper/plastic)	
depletion	refillable + recyclable	non recyclable + renewable/non-renewable	bottle
pollution	cleaning harmful + recycling non-harmful	dumping/burning non-harmful	carton

Figure 6.16 – Content standard for the bottle/carton decision-making situation in terms of a schematic summary of the scenario's 'perfect' reasoning reproduced in figure 6.15.

Reformulation and criticism – By way of example, first the reformulation of one student's argumentation resulting from the small-group work on task 13 is presented below: first the factual utterances in figure 6.17, followed by a reformulation in words and in a schematic way in figure 6.18. A comparison between this scheme and the content standard of figure 6.16 results in a criticism of the argumentation's

content. The additions in the scheme that make the factual utterances into an explicitly coherent and sensible argumentation are printed in italics. These additions reflect a criticism of the argumentation's presentation. The example has been selected because it fully reflects the *reformulation rules* that have emerged during this activity. These rules will be presented in a reflection on the method of reformulation somewhat further on in this section.

S_1 Depletion – The bottle can be recycled and the carton takes far more effort to use again so it gives depletion with carton running out more quickly.
Pollution – With milk bottle (gives chlorine pollution) easier recycling and with carton they first have to separate the plastic and paper and that takes much longer.
Choice – The plastic bottle because that's being recycled and the paper/plastic isn't.

Figure 6.17 – Student workbook: factual utterances of a student as a result of the small-group work on task 13.

The remark about 'chlorine pollution' at first sight seems strange. However, the presentation in task 16 may offer a clue. In the discussion about the presentation of the group which includes the student (S_1) concerned, it appears that this chlorine is thought to be the cleaning agent used for cleaning bottles before refilling. The remark about 'chlorine pollution' (thus) indicates that the student is considering the bottle as being 'refillable'. His remarks about recycling the bottle might then be understood as 'recyclable' after refilling it a number of times. Regarding the carton the qualification overtly is 'non-recyclable', at first a bit hesitatingly (takes more effort, takes much longer) but somewhat later rather decidedly. On the criterion of depletion this would result in a choice for the bottle, which is indeed suggested in the student's utterances. On the criterion of pollution no qualification of the carton is being given. This gives rise to two possible interpretations: dumping/burning of the carton is perceived as being either 'harmful' or 'non-harmful'. On the first interpretation the comparison of the alternatives on the criterion of pollution would turn out to be neutral. The necessary weighting would then be trivial, leading up to a final choice for the bottle as stated in the student's utterances. A problem with this qualification of the carton on pollution is that it is not in line with the information provided by the reference materials used in the unit's investigation phase. However, it has already been noted that the students in general are not convinced of this information being correct. Quite a number of other students in this task therefore explicitly qualify the dumping/burning of the carton as being 'harmful'. Therefore, qualifying the carton on pollution as being 'harmful' in this first interpretation is defendable as this is more in line with the students' (unchanged) pre-knowledge. On the second interpretation the comparison of the alternatives on the criterion of pollution would turn out in favour of the carton: cleaning bottle 'harmful' versus dumping/burning carton 'non-harmful'. The necessary weighting then would be non-trivial, but might of course result in a final choice for the bottle. However, this second interpretation seems to be less probable as one would expect the student to

make a remark about the difficulty of making a final choice in a case of conflicting choices per criterion. Such a remark cannot be found in the student's utterances. Therefore, the first interpretation seems to be the most probable one. This reformulation of the student's utterances of figure 6.17 has been reproduced in a schematic way in figure 6.18.

The contents of this student's argumentation can be criticised by comparing the reformulation of figure 6.18 with the content standard for this decision-making situation in figure 6.16. The alternatives and criteria comply with the content standard – as is to be expected given the structure of task 13. The criticism concerns the comparison on the criterion of depletion being incomplete: a lacking qualification 'refillable' for the bottle, and a lacking additional qualification of 'renewable/non-renewable' for the carton (paper and plastic, respectively). Although the choice for the bottle on the criterion of depletion in the reformulation is understandable, this additional qualification is necessary, as a qualification 'renewable' would lead up to a neutral choice on this criterion. The criticism could also concern the incorrect qualification of the carton on the criterion of pollution, but given the apparently existing and unresolved confusion on this point it would not be fair to blame the student for this. Nevertheless, the student's argumentation assessed against the content standard is partly incomplete and partly incorrect.

criterion	comparison bottle (plastic)	carton (paper/plastic)	choice	weighting	final choice
depletion	*refillable* + recyclable	non-recyclable	*bottle*		
pollution	cleaning harmful	*dumping/burning harmful*	*neutral*	*trivial*	bottle

Figure 6.18 – Reformulation of the student's factual utterances reproduced in figure 6.17.

The other students' utterances have been reformulated in the same way as in the above example. With respect to the content of these reformulated argumentations it appears that almost all students compare the packaging alternatives on the two environmental criteria of depletion and pollution. The comparison between the reformulations and the content standard of figure 6.16 did show that the students' comparisons of the alternatives on both environmental criteria are amenable to improvement. Not one out of the nineteen interpreted and reformulated argumentations could be considered 'perfect' in the sense of displaying complete and correct qualifications of both alternatives on both criteria. The incomplete and/or incorrect qualifications occurring most frequently (that is, in more than half of the argumentations) are the following: an incomplete qualification 'refillable/recyclable' of the bottle on depletion, a lacking additional qualification 'renewable/non-renewable' of the carton on depletion, and incorrect qualifications of the bottle and carton on pollution. As already noted, the incorrectness of the qualifications on pollution point at a weakness in the unit's investigation phase.

From this analysis of what the students have been writing down in their workbooks in task 13 it appears that they do use their extended issue knowledge, but only to some extent as the content of their argumentation does not yet fully comply to the content standard of a 'perfect' reasoning in the decision-making situation at hand. According to the scenario this was to be expected, and the purpose of the ensuing whole-class discussion would then be to use these results of the students' small-group work for arriving at such an exemplary 'perfect' reasoning. However, the scenario cannot be considered adequate in this respect. First of all, it does not clearly enough state the essential elements of such a 'perfect' reasoning in the decision-making at hand that probably will have to be addressed in the whole class discussion. Secondly, it does not give any procedural specifications on how to do this. And thirdly, it does not stress the necessity of reflecting on the character of the 'perfect' reasoning resulting from the whole-class discussion in this task. In other words, in terms of the more sharply defined new purpose of this task, the scenario is far too vague about the purpose of developing and making explicit a content standard for an argued point of view, as well as the procedure to be used for arriving at this aim in classroom practice.

Scenario revision – The results of the above analysis, combined with earlier remarks about classroom practice, could be seen as a starting point for the necessary revision of the scenario concerning task 13 to make this task fulfil its now more sharply defined new purpose of developing and making explicit a content standard for an argued point of view. The teaching practice to be described in the revised scenario would differ in six aspects from the whole-class discussion during the second trial: an explicit instruction for the students to use their 'summary of extended issue knowledge' from task 11 (instead of a remark about using the reference materials), a different question for starting the whole-class discussion (comparison on depletion and pollution, respectively, instead of final choice), visualisation of the argumentation-under-construction (use of the blackboard to support the students' memory by keeping track of what is being put forward in a scheme representing the task's structure such as those in figures 6.16 and 6.18), developing a content standard (complete and relevant alternatives and criteria, and complete and correct comparisons per criterion through strategic further questioning and structuring), making explicit this content standard (through reflecting on the interactively constructed argumentation), and making explicit the progress in the students' learning process (through reflecting on the different outcomes of the comparable tasks 7 and 13).

As far as the element of developing a content standard in the above outline is concerned, it is now expected that the whole-class discussion will have to address at least two out of the three earlier identified most frequently occurring deficient qualifications: an incomplete qualification 'refillable/recyclable' of the bottle on depletion (as this influences the bottle's qualification on pollution), and a lacking additional qualification 'renewable/non-renewable' of the carton on depletion (as the qualification 'renewable' would render a different choice on this criterion: neutral instead of bottle). It is expected that the qualifications of the bottle and carton on

pollution will be correct more frequently, if these have been properly addressed in the unit's investigation phase.

Conclusion – The above outline of the scenario's revision with respect to developing and making explicit a content standard indicates that task 13 has at least the potential to fulfil its more sharply defined new purpose. That is, an elaboration of the scenario along the lines given above very probably could be considered 'good enough' for teaching practice – but still remains to be tested.

Presentation standard

The second case of stagnation in the teaching/learning process is during the students' reporting in task 16. The more sharply defined purpose of this task is to develop and make explicit a presentation standard for an argued point of view. An additional purpose of task 13 then is to prepare the students for this, through making the interactively constructed argumentation an example of a well-presented argued point of view. The reformulations of the students' factual utterances from the small-group work in task 13 will also help to identify what most probably needs to be addressed in teaching practice. As stated earlier, a comparison between the students' factual and reformulated utterances will yield a criticism of the students' *presentation* of their argued point of view. As this criticism will not be explicitly dealt with in task 13, it can be expected that it will also apply to the students' presentations of an argued point of view in task 16. Therefore, this criticism can act as a guideline for the teacher in listening and reacting to the students' presentations.

The results of this analysis of the students' performance in task 13 will be presented below, followed by a similar analysis of the student's presentations in tasks 16. This second analysis will serve to assess whether it would have been possible to actually develop and make explicit a presentation standard, provided the scenario had been adequately tuned to reaching this aim.

Reformulation and criticism – With a view to developing and making explicit a presentation standard in task 16, the comparisons between the reformulations (as a presentation standard) and the students' factual utterances in task 13 show in all but two cases a clear reproduction of the alternatives and criteria. However, the reproduction of the comparison of these alternatives on these criteria in roughly half of the cases (8 out of 19) must be qualified as not being systematic, caused by a lacking qualification of one or more alternatives on one or more criteria. What is lacking in almost all cases is an explicit reproduction of the choices per criterion and of a weighting resulting in a final decision. The earlier example of a student's utterances in figure 6.17 is also exemplary in this respect. The lack of an explicit reproduction of the choices per criterion is understandable, as a presentation standard has not yet been developed and the format of the task does not 'force' students to reproduce these choices. A simple revision of this format therefore might be considered desirable. The lack of an explicit reproduction of a weighting of these choices is also understandable, as in all cases the required weighting is trivial: the

reformulated choices per criterion are not in conflict, a weighting therefore is trivial and a reproduction of something trivial is quite rightly not thought necessary by the students. Mostly, the non-trivial weighting is the result of lacking or incorrect qualifications of the alternatives on the criteria. Correcting these will result in conflicting choices per criterion – as expected in the scenario.

The students' presentations about their self-chosen decision-making situations in task 16 can be expected to show the above-outlined 'deficiencies': a non-systematic comparison of alternatives on the criteria, and a lack of an explicit reproduction of the choices per criterion and of a weighting resulting in a final decision. A similar analysis (that is, a comparison between reformulation and factual utterances) of the students' presentations in task 16 has shown that these could indeed be considered deficient in this respect. However, the same analysis also showed that, under the unfavourable condition of not having a clear example of a well-presented argued point of view, after only three presentations the presentation standard could have been fully addressed implicitly through adequate feedback by the teacher. The first group of students presents the case of packing eggs in a container of either plastic or carton, with a clear reproduction of the alternatives and criteria and with a systematic comparison of these alternatives on these criteria – which could have been identified, explicitated and valued by the teacher. So far, this report is an example of a well-presented argued point of view (apart from possible criticisms regarding the contents). What is to be criticised – in a friendly way, of course, while emphasising the aim of *learning* to clearly present an argued point of view – is the lack of an explicit reproduction of the choices per criterion and of a weighting resulting in a final decision. The report of the second group of students about packing vegetables in paper, plastic, steel or glass – maybe as a result of the relatively large number of alternatives – reflects a non-systematic presentation of the comparison of these alternatives on their clearly stated criteria, resulting in an incomplete and unclear presentation of choices per criterion and final choice. This presentation therefore could have been used in the whole-class discussion for pointing at the importance of a systematic reproduction of the comparison of the alternatives on the criteria. Finally, the third group of students addresses the decision-making situation of coke in a bottle or a can, leaving out a comparison of their alternatives on one of the environmental criteria. If this omission had been addressed in the whole-class discussion, a non-trivial weighting of the choices per criterion leading up to a final choice would have emerged. This would have pointed at the final element of the presentation standard: the necessity of an explicit reproduction of the weighting of the choices per criterion in order to make the final choice understandable.

Scenario revision – The results of the above analysis could be seen as a starting point for the necessary revision of the scenario concerning tasks 13 and 16. The teaching practice to be outlined in the revised scenario for task 13, in addition to what has already been said about that in the context of developing and making explicit a content standard, would then also have to anticipate on developing and making explicit a presentation standard, e.g., through making reference to what

(also) has been done during the whole-class discussion in task 13: systematic comparison of the alternatives on the criteria, explicit choices per criterion, and explicit weighting of these choices to arrive at a final choice – without yet demanding their inclusion in a presentation of an argued point of view. The feedback on a first set of students' reports during task 16 could then concentrate on gradually making explicit the presentation standard. After such an explicitation at an appropriately chosen point, the students that still have to do their presentation could be given the task of reviewing their already prepared presentation in the light of the now explicit presentation standard. The other students could be given the task of 'assessing' the remainder of the presentations by comparing them to the established presentation standard.

Conclusion – This outline of the scenario's revision with respect to developing and making explicit a presentation standard indicates that task 16 has at least the potential to fulfil its more sharply defined purpose, provided that task 13 not only fulfils its purpose of developing and making explicit a content standard, but also fulfils its additional purpose of preparing for developing and making explicit a presentation standard in task 16. A second condition is that during task 16 the teacher can focus on giving appropriate feedback, without being distracted by having to pay attention to the content of the reports because of disagreements about the alternatives' qualifications on the environmental criteria. This problem should have been solved somehow in the unit's investigation phase, as already indicated. An elaboration of the scenario along the lines given above very probably could be considered 'good enough' for teaching practice – but still remains to be tested.

It must be further noted that the teacher's task of guiding the students in 'developing standards' during this application phase of the unit is not at all an easy one. The necessity of an appropriate preparation with the help of selected instances of classroom practice during the second classroom trial and the revised, more detailed scenario is obvious.

Methodological reflection

In this section a method of *reformulation* has been used to retrospectively interpret the students' factual utterances in an appropriate way, with the aim of coming to really understand what they have been writing and saying. Such an understanding was considered necessary in order to be able to turn the vague dissatisfaction with the progress of the teaching/learning process into an assessment of the quality of the content and presentation of the students' argued point of view in a decision-making situation, on which the above outlined direction of the scenario's necessary revision could be based. In reaching such an understanding, a number of rules seem to have been developed and followed. These *reformulation rules* are made explicit below. A general overlying principle in applying these rules is that the students' utterances are seen as being sensible and coherent, even if at first sight they do not appear to be so.

- The *factual utterances of a student* are considered *as a whole*. So, if a student makes a remark about refilling a bottle when presenting his or her final choice, this

utterance is included in the reformulation at the appropriate place 'prescribed' by the content standard – in this case as a qualification of the bottle on the criterion of depletion. Another example of this can be found in the student's utterances and accessory reformulation of figures 6.17 and 6.18: the student's final qualification of the carton as 'non-recyclable' in explaining his final choice is 'moved' to the comparison on depletion in the reformulation.

- In extension of the first rule, the *factual utterances of two or more co-operating students* (small-group work) are considered *as a whole*, disregarding the sometimes somewhat different wordings used. This means: more clear or additional utterances of one of the students are also considered to be applicable to the utterances of the other student(s). Unless, of course, this results in inconsistencies in the utterances of the other student(s) – but then the wordings are too different anyway.
- The *additions to the factual utterances* are being limited to what is *minimally necessary* to make the explicit or suggested choices per criterion and the final choice understandable. If a student in his or her factual utterances qualifies the bottle and carton on depletion as 'recyclable' and 'non-recyclable', respectively, then a choice falling on the bottle on this criterion is understandable. The qualifications 'refillable' and 'renewable/non-renewable' of the bottle and carton, respectively, are then not added, although according to the content standard this would be necessary for a complete comparison on the criterion of depletion. An example of this can again be found in figures 6.17 and 6.18: the additional qualification 'renewable/non-renewable' of the carton on depletion has not been added in the reformulation. For the same reason the qualification of the bottle on pollution with respect to recycling as being 'non-harmful' has not been added: such an addition would not influence the choice on this criterion. However, the qualification 'refillable' of the bottle on this criterion has been added in this case, as this addition seems to be necessary to understand the bottle's qualification on the criterion of pollution.
- If additions are necessary as a result of lacking qualifications of one or more alternatives on one or more criteria, and if there is *more than one option for such an addition*, then the choice is determined by (a combination of) two factors: the student's *estimated knowledge* and the *necessary weighting* leading up to the student's final choice.

If a student qualifies the bottle on depletion as 'refillable' and on pollution only indicates that the bottle is being cleaned, the qualification 'non-harmful' is added. Unless, of course, this leads to an incomprehensible final choice, because then the argumentation would be incoherent. If a student qualifies the carton on depletion as 'non-recyclable' and does not indicate whether or not the carton contributes to pollution, the qualification 'dumping/burning harmful' is added – again: unless this leads to an incomprehensible final choice. In both examples the choice for the additional qualification is determined by the *estimated knowledge* of the student. These estimates in general are based on what has happened during the preceding part of the unit (where cleaning refillable packages has been dealt with too minimally and where the discrepancy between the students' everyday life knowledge and the information in the reference materials about pollution has not been solved). But

these estimates can also be based on what other students are explicitly putting forward in their argumentation (such as a qualification of 'dumping/burning harmful' on pollution/carton) or – incidentally – on what the student concerned is putting forward in another task. An example of this can again be found in figures 6.17 and 6.18: on the criterion of pollution the qualification of cleaning the bottle as being 'harmful' has been based on additional utterances of this student on another task, and the qualification of dumping/burning the carton as being 'harmful' has been based on what has happened during the preceding part of the unit and on what therefore is being put forward by a majority of the other students.

The *necessary weighting* is playing a role if one option leads to a non-trivial weighting (as a result of conflicting choices per criterion) and the other option leads to a trivial weighting. In this case the choice is on the second option, if in the factual utterances an indication of weighting is lacking. An indication of weighting is always necessary, but for the sake of a clear presentation a lacking trivial weighting is less 'serious' than a lacking non-trivial weighting. An example can again be found in figures 6.17 and 6.18: the decision about which interpretation to prefer regarding the qualification of the carton on the criterion of pollution has been based on the student's estimated knowledge *as well as* on the absence of an indication of non-trivial weighting.

- If in the process of reformulation it appears that *inconsistencies cannot be dissolved*, then by definition a reformulation is *not possible*. These inconsistencies might concern contrary qualifications of one alternative on different criteria (such as the qualification 'recyclable' and 'non-recyclable' of the carton on depletion and pollution, respectively) or a discrepancy between the choices per criterion and the final choice (such as a choice for the bottle on both criteria and a final choice for the carton). In such cases a reformulation is only possible on the basis of additional information, which the student will be able to provide, of course, given that he or she will appreciate that, as having been interpreted, the utterances come out as incoherent – and probably the student will point out where he or she has been misinterpreted. This situation has not been encountered during the reformulation work. However, in some cases arriving at a reformulation has been rather difficult. Especially in those cases it would have been desirable to check with the student whether the reformulation indeed represents what he or she intended to say (though, of course, such a check is never a bad thing to do).

6.7 The reflection phase: reflecting on extended knowledge

The question to be answered in this section about the trial of the unit's reflection phase as described in chapter 4 (section 4.6), given its purpose, is:

- *Does this teaching/learning activity make students reflect on their decision-making experiences relating to the decision-making procedure and the character of their extended knowledge, and tentatively explore the usefulness of these experiences in the light of the global motive?*

Classroom trial

The reflective character of this final phase of the unit is not very clearly stated. The teacher makes some reference to the students' decision making in the application phase and the environmental decision-making situations in the motivation phase of the unit. However, it is questionable whether the main point of this final part of the teaching/learning process has come across: see if what has been done and learned about package-related decision making might also have some relevance for decision making on other environmental issues – as suggested in the motivation phase of the unit.

Task 17: Decision-making process – Constructing the model of the decision-making procedure with the help of the task's puzzle format presents no problems. The accompanying stories about the puzzle's solution written by the students show that a large majority explicitly or implicitly describes the decision-making procedure as comparing packaging alternatives on the two established environmental criteria (depletion and pollution). The fact that those comparisons per criterion are a prerequisite for choosing between the alternatives is less often explicitly stated. This could be caused by the lack of attention paid to this aspect of decision making in the discussion of task 13. However, it might also be a matter of the difficulty with expressing themselves clearly that students of this ability level experience, or a matter of not thinking it necessary to describe evident links between the consecutive steps in the procedure. The lack of attention paid to the necessary weighting of comparisons in the whole-class discussions has its repercussions on the students' stories: only a small minority of the students writes something that could be interpreted as pointing in the direction of this aspect.

The description of the knowledge input into this decision-making procedure presents the students with no difficulty as far as the environmental criteria are concerned, as expected. However, the kind of knowledge necessary for comparing alternatives on those criteria appears to be more difficult, as is apparent from the whole-class discussion in figure 6.19.

T Depletion and pollution. Now, which kind of knowledge did you need for being able to compare packaging alternatives on those criteria?

S_1 Whether it's recyclable.

T Recyclable, yes.

S_1 Whether it contains harmful substances.

T Harmful substances ... In general: you've got to have knowledge, you have to know things about all those five packaging materials. Agreed?

S^s Yes.

T Knowledge about packaging materials. Knowing about their properties ... about depletion: how much time before they run out, given today's consumption rate. Those kinds of things you have to know, otherwise you won't be able to present an argued point of view.

Figure 6.19 – Whole-class discussion: reflecting on the knowledge input into the decision-making procedure.

The students do not get much opportunity to voice their answers to this reflective question. The teacher is falling back into his teaching role, is not connecting to what the (one) student is putting forward and in his final statement is being rather incomplete in comparison with the intended answer of 'knowledge about how the packaging materials are scoring on the two environmental criteria'. The character of the necessary knowledge input into the decision-making procedure therefore will very probably remain unclear to the students.

Task 18: Decision-making in other situations – The task is introduced as reproduced in figure 6.20, containing a reasonable transition from task 17 to task 18. It seems that the students themselves connect to the environmental decision-making situations in the motivation phase of the unit.

T Such an argued point of view ... would this also be applicable to those other environmental topics in everyday life? Which were those? Now we've looked at materials, haven't we ... as an environmental issue. Which were those other two environmental issues?
S_1 Eh ... water.
T Water, yes. And?
S_1 Energy.
T And the use of energy. Those were the other two, yes. Now would this also work, the things we've been doing with packaging materials ... would this also work when we're going to talk about energy?
S_2 I think so, yes.
T And would this also work when we're going to talk about water. Yes, he [S_2] says. Well, let's see ... that's what this final task is about.

Figure 6.20 – Whole class discussion: reflecting on decision making about other environmental issues.

In the whole-class discussion following the small-group work it clearly comes forward that the students expect the environmental criteria of depletion and pollution to play a role in all environmental decision-making situations. What complicates the discussion are the combinations of water and energy use and of materials and energy use in two of the three selected decision-making situations in this task. In itself this broadening of the decision-making situations is correct and could even be considered desirable. However, the whole-class discussion jumps to and fro between these aspects without the aspect under discussion being made explicit, without triggering questions for further investigation and without reaching some kind of conclusion. So, this task is discussed in a too confusing and superficial way. Therefore, an indication of a new need for knowledge about criteria-related properties of water and energy as a starting point for follow-up units about these other environmental issues does not clearly emerge.

Evaluation

The above-given description and illustration of classroom practice will again first be discussed in the light of the design/research question about the unit's reflection phase. In conclusion, this question will be answered.

Discussion – The difficulty the students experience in expressing their perception of the decision-making procedure in task 17 might be explained by the lack of explicit attention paid to specific aspects of this procedure in the preceding phase, especially the aspects of a comparison-based choosing between alternatives per criterion and a weighting of these comparisons. Therefore, this experienced difficulty might result from the identified stagnation of the teaching/learning process during the application phase of the unit. An effort directed at developing and making explicit the content and presentation standards (as suggested in the previous section) might be enough to solve the students' difficulty in this respect.

The teaching/learning process also seems to come to a standstill in task 17, when students are asked to answer the question 'which *kind of knowledge* did you need for being able to compare the packaging alternatives on those environmental criteria?' It is not that students did not come up with concrete ideas about a required knowledge input into the decision-making procedure, probably based on their previous experiences with decision making about packages in the unit so far, but rather that those ideas have not been used productively to arrive at the intended characterisation of the required knowledge input as 'knowledge about how the packaging materials score on the two environmental criteria'. The scenario should pay more attention to the question of how to turn the students' concrete ideas into this more abstract formulation, suitable for being transferred to the next task about the necessary knowledge input concerning other environmental issues. Once this more abstract formulation of the necessary knowledge input is established, the final task 18 can be expected to be more successful in its aim of providing a starting point for follow-up units, emphasising the relevance of the explicit decision-making procedure and the analogies with respect to environmental criteria, and criteria-related knowledge about materials, water and energy as a necessary knowledge input into this procedure.

What did become apparent during this part of the trial is that the consecutive tasks in the application and reflection phases are interrelated. On the one hand, the problem in the application phase concerning the 'development of standards' clearly had repercussions on the students' reflection on their decision making in the final phase. On the other hand, the problem in the reflection phase concerning the kind of knowledge required for decision making on the waste issue had its repercussions for decision making about other environmental issues. As noted, these repercussions are understandable and perhaps even unavoidable under the occurring conditions.

Conclusion – The answer to the design/research question for the final phase of the didactical structure cannot yet be a clear yes, due to the earlier mentioned stagnation of the teaching/learning process in the preceding application phase, and to another such stagnation in the reflection phase itself. The elaboration of the reflection phase is not yet 'good enough' for practical purposes. The sequence of tasks seems quite fine – at least for the time being. However, a fine-tuning of the scenario is needed in the form of an appropriate teacher guidance to make students arrive at a general description of the required knowledge input into the decision-making procedure, and

to let them use this in order to establish preliminary questions concerning other environmental issues. Such a fine-tuning of the scenario and an appropriate teacher preparation would probably be 'good enough' to dissolve the identified stagnation of the teaching/learning process in classroom practice – but also this still remains to be tested.

6.8 The questionnaire: students' perception of the teaching/ learning process

In order to get an idea of the students' appreciation of the unit in general and specific working methods in particular, and of their perception of the coherence of the teaching/learning process, a post-trial questionnaire was administered to the students directly after finishing the unit. This questionnaire will first be described. In presenting the results, it is tried to connect these to the findings concerning class-room practice.

Post-trial questionnaire
The post-trial questionnaire is reproduced in figure 6.21. The first and third part of the questionnaire were meant to get a global impression of the students' appreciation of the unit with respect to the topic and working methods. The second part of the questionnaire was meant to get a global impression of the students' perception of the coherence of their learning process.

Questionnaire

Packaging waste: dumping, burning and reusing/recycling

In the past series of lessons you have worked on the topic of *packaging waste*. As you know these lessons are being investigated, because your class has been working on this topic in a special way. We therefore are curious to know about your experiences.

Below you find a number of questions about the past series of lessons. If necessary, feel free to take your workbook for seeing what you did in those lessons.

1 General impression

Tell something about the lessons on the topic of *packaging waste* in general. For example:
- What did you learn in those lessons?
- Did you learn a lot, or not?
- What was the most important thing that you did learn? And what did you think was unimportant?
- Are there things about which you – through these lessons – did change your mind?
- What did you enjoy in those lessons, and what was tiresome?
- What was good in those lessons, and what was bad?

- According to you, what should be done better or different?
- What did you think of the lessons if you compare them to the other physical science lessons you have taken this year?

2 Contents

The workbook for the series of lessons about *packaging waste* consists of five activities (or: chapters). Below you find a number of questions about each of those activities.

- The *first* lesson dealt with *environmental decision-making situations* (activity 1). After this first lesson, did you have a clear idea about *what* would happen during the consecutive lessons, and *how* that would happen? Or were these consecutive lessons dealing with things quite different from what you expected after the first lesson? If so: what things were those?
- The *second* lesson dealt with *packaging decision-making situations* (activity 2). And near the end of that second lesson you wrote down *research questions* (task 9). After this second lesson, did you have a (more) clear idea about *what* would happen during the consecutive lessons, and *how* that would happen? And did you have the idea that those research questions dealt with things you did not yet know?
- In the consecutive lessons you have first sought an *answer* to the research questions (activity 3). After those lessons, did you have the idea that you had found an answer to those questions?
- After that you have used that new knowledge for making an *argued choice between packaging alternatives* (activity 4). In those lessons, did you have the idea that you were better able to make such a choice?
- And finally, in the last lesson you have looked backward on your *decision-making experiences* during the preceding lessons (activity 5). After this lesson, did you have the idea that you knew better how to tackle *other environmental decision-making situations* (that is: other than concerning packages)?

3 Working methods

At times in the series of lessons you have been working in a way different from what you have experienced so far in physical science lessons: you have solved puzzles (tasks 5 and 17), you have been engaged in independent small-group work when *looking for answers to research questions* (tasks 10 and 11) and when *making a choice between packaging alternatives* (task 15), you have *given a presentation about that choice* before the class and you have *listened to the presentations* of your fellow-students (task 16).

- What did you think of these different ways of working: enjoyable or tiresome, difficult or easy, and useful or useless?

Figure 6.21 – Post-trial questionnaire.

The open questions in the first and third part of the questionnaire concerning the unit in general and specific working methods in particular were considered enough to trigger the students' reflection on the unit as a whole. As a reflection on the coherence of the teaching/learning process was thought to be more demanding for the students, the second part of the questionnaire was made up of a series of questions of a more closed character with rather specific formulations and a suggested yes/no/neutral answer format. However, one might wonder whether assessing the students' perceived coherence of the teaching/learning process could be done in this way. It asks students to think back to their learning experiences at specific points of the unit, most of which were already lying quite some time in the past. And as far as they would be able to remember what they had been thinking at those points, these recollections at the time of administering the questionnaire would probably be

coloured by what happened during the remainder of the teaching/learning process. The results of this part of the questionnaire will therefore have to be interpreted with quite some caution. In retrospect, a series of small-group on-trial and post-trial interviews might have been a more appropriate and informative research instrument. It would have given students the opportunity to clarify their initial answers and their interpretation of the questions asked.

Perception of the teaching/learning process

The results of the post-trial questionnaire concerning the students' appreciation of the unit's *topic* and *working methods*, and their perceived coherence of the *teaching/ learning process* could be summarised as follows.

Topic – A large majority of the students indicates to have learned much about the topic, mainly in the area of criteria-related properties of packaging materials. In this area 'learning about pollution' is scoring relatively high, maybe because the unit's contents on this point clearly differ from the students' pre-knowledge. This is explicitly indicated by two students: 'that burning it is less polluting' and 'burning plastic without PVC gives no pollution (but I still have my doubts about that)'. The majority of the answers being in this category of criteria-related properties of packaging materials is in line with the already confirmed assumption about the students' pre-knowledge.

A second, but smaller category of students' reactions to the topic of the unit relates to decision making: 'how to decide about the best package', 'how to compare packaging materials', 'environmental criteria' and 'decision-making situations'. This might be considered to indicate the students' awareness of the reason for learning about the above mentioned criteria-related properties of packaging materials.

Working methods – In considering the strong and weak points of the unit, the students clearly appreciate the experiments and consider 'the tasks' in general to be tiresome or even boring and too lengthy. With respect to these tasks the students are asking for more variety and, more often, less repetition. It does not become very clear what the students do mean in this respect, but it might be suspected that they point at the frequent, and at times lengthy and confusing whole-class discussions. More specific, their criticism might concern the identified stagnation of the teaching/learning process during the whole-class discussions following each presentation in the *application* phase of the unit, where the idea of 'all of this being more and more of the same' has been put forward by some of the students.

In their general impression, the 'new' working methods (such as solving puzzles, finding answers to their research questions, choosing between packaging alternatives and reporting about that) are only incidentally mentioned by students as strong or weak points, with a rough balance between a positive and negative appreciation. When specifically asked about their appreciation of those working methods, the result is generally positive in terms of enjoyment and perceived usefulness.

In comparison to the 'ordinary physical science lessons' the unit is perceived as being more enjoyable, by girls distinctly more so than by boys – despite the generally perceived tiresome character of 'the tasks'.

Teaching/learning process – In the second part of the questionnaire the students have been asked to reflect on the coherence of the global teaching/learning process as perceived by them. The students' answers to the questions in this part of the questionnaire are summarised in a yes/neutral/no format in the table of figure 6.22. As already noted, the validity of the results of this part of the questionnaire is questionable. Therefore, an attempt will be made to connect the trends in the students' answers to the observations of classroom practice.

Question	Answer		
	yes	neutral	no
Activity 1 – Did you have a clear idea about what would happen during the consecutive lessons, and how that would happen?	6	3	14
Activity 2 – Did you have a (more) clear idea about *what* would happen during the consecutive lessons, and *how* that would happen?	12	8	3
Activity 2 – Did you have the idea that those research questions dealt with things you did not yet know?	10	10	3
Activity 3 – Did you have the idea that you had found an answer to those questions?	17	4	2
Activity 4 – Did you have the idea that you were better able to make an argued choice between packaging alternatives?	18	3	2
Activity 5 – Did you have the idea that you knew better how to tackle other environmental decision-making situations?	12	7	4

Figure 6.22 – Summary of the students' answers to the second part of the questionnaire about their perceived coherence of the teaching/learning process.

After the unit's motivation phase (activity 1), the majority of students indicates not yet to have had a clear idea about what was going to happen during the rest of the lessons. This situation has considerably improved after the unit's question phase (activity 2). Now roughly half of the students answer the question whether they had a (more) clear idea of what would happen in the consecutive lessons in an affirmative way, with only a small minority indicating a still non-coherent teaching/learning process. Roughly the same number of students indicates that they perceived the questions for further investigation as dealing with 'things we did not yet know', but, on the other hand, also a relatively large number of students reacts neutrally to this question.

These trends in the students' answers concerning the questions about the purpose of the units' motivation and question phases (activities 1 and 2, respectively) seem to be roughly in line with the intended global teaching/learning process of gradually building up a view on their prospective learning process, and with the observed classroom practice of looking backward and forward at the end of the question phase

as described in section 6.4. However, the relatively large number of students answering neutrally to the questions about the unit's question phase seems to indicate that the problem-posing character of the teaching/learning process is not clearly obvious to the students. This might have to do with the problematic classroom practice with respect to identifying the questions for further investigation in the context of a decision-making situation as described in section 6.4, where a reconstruction of the teaching/learning process was needed to make some sense out of what actually happened in classroom practice.

With respect to the remainder of the teaching/learning process the data about its perceived coherence indicate that a large majority of the students has the idea of having found answers to their questions for further investigation after the unit's investigation phase, and of being better able to tackle decision making about packages with the help of these answers in the application phase of the unit (activities 3 and 4, respectively). Their reaction to the question of being better able to tackle environmental decision-making situations after the unit's reflection phase (activity 5) is somewhat more hesitating: the number of students answering in an affirmative way goes down to roughly half, and the number of students answering neutrally and negatively goes up compared to their answers to the previous questions.

This trend in the students' answers concerning the questions about the purpose of the units' investigation, application and reflection phases does not seem to be completely in line with the observed classroom practice. The students' positive reaction to the question about the purpose of the research phase corresponds with the relatively unproblematic way in which this teaching/learning activity was carried out. That students also judged the application phase as rather positive, however, may seem strange in the light of the above evaluation of classroom practice. The identified stagnation and unclear purpose of the teaching/learning process in this phase does not seem to be perceived by the students as such. This might be explained by the lack of appropriate feedback on the students' decision-making efforts with the aim of a development and explicitation of a content and a presentation standard, which probably has given them the impression that they were indeed 'better able to make an argued choice between packaging alternatives' as stated in the questionnaire. The students' somewhat more hesitating reaction to the question about the purpose of the reflection phase corresponds with the observation of a somewhat confusing classroom practice in which the applicability of what has been learned about packaging-related decision making to other environmental decision making is not being addressed clearly enough.

Conclusion – From the questionnaire data it might be concluded that the students do appreciate the unit, relative to their ordinary physical science lessons. This seems to be in line with the observed positive attitude and involvement during the trial. From the data it might also be concluded that the students' self-assessment of their learning corresponds with the already confirmed assumption about their pre-

knowledge. Finally, it might be concluded – although with quite some reservation – that the students in their reflection have perceived the teaching/learning process as coherent to a reasonable degree, with a loss of coherence at roughly those points where the observed classroom practice appears to considerably deviate from the lines set out by the scenario or where the scenario does not clearly outline the path to be taken (that is, in the question phase and in the reflection phase of the unit, respectively). The students' perception of coherence at the point where the scenario is clearly deficient (that is, in the application phase of the unit) is the exception to this 'rule', which might be explained by the lack of appropriate feedback on the quality of their input into the teaching/learning process.

6.9 The content test: the unit's learning effects

As the standard teaching procedure at the trial school includes an end-of-unit content test for assessment purposes, also in this case such a test was administered. From a research point of view the validity of this content test is probably questionable, as it does not cover the students' specific issue knowledge to a sufficient degree. However, an analysis of the students' responses to the questions in this test could give an impression of the unit's learning effects – especially in the area of the presentation of an argued point of view in packaging decision-making situations. The content test will first be described. In presenting the results, it is again tried to connect these to the findings concerning classroom practice.

Content test
The content test used for assessment purposes is reproduced in figure 6.23. The test consists of a number of open questions, which can be grouped in three parts. The first part of the test (questions 1 and 2) relates to general knowledge about packages as has been dealt with in the unit's question phase: the reasons for packing products, the environmental problems related to packaging and the solutions for these problems. The second part of the test concerns different aspects of presenting an argued point of view in package-related decision-making situations as has been dealt with in the unit's application phase: identifying a packaging decision-making situation and the environmental criteria for comparing the alternatives (question 3), presenting an argued point of view in a given decision-making situation (question 4), identifying the points to pay attention to in clearly presenting an argued point of view (question 5) and commenting on a given argumentation (question 6). It was expected that part of these questions (more specifically the questions 4 and 6) would also provide some data on the students' specific issue knowledge in terms of the criteria-related properties of packages and packaging materials. Therefore, specific questions aimed at assessing the students' specific issue knowledge were not included in the test. Finally, the third part (question 7) addresses the decision-making procedure that has been made explicit in the unit's reflection phase. The teacher considered this test adequate for assessment purposes.

Content test

Packaging waste: dumping, burning and reusing/recycling

1 Packages

At a shop most products are sold in a *package*: a box, bag, can, bottle etc.

- State three reasons for packing products. For each of these reasons, give an example from everyday life practice.

2 Environmental problems and solutions

Compared to the past, now far more products are sold in a disposable package.

- Which *environmental problems* does this disposal of empty packages give?
- Which *solutions* are there for those environmental problems? For each of these solutions, give an example from everyday life practice.

3 Packaging decision-making situations

Sometimes it is possible to buy the same product in different packages. Then you have to do with a *packaging decision-making situation*: you can choose between two or more *packaging alternatives*.

- Think of an example of a packaging decision-making situation. Describe this decision-making situation as clearly as possible: what is the *product*, what are the *packaging alternatives*, and which *materials* are these packages made of?
- What do you have to know about these packaging materials in order to be able to choose?

4 Decision-making situation

In quite a lot of shops the things you bought are put in a carrier bag. Mostly such a carrier bag is made of plastic, sometimes made of paper.

- According to you, what seems to be the best carrier bag: the one made of plastic, or the one made of paper? Give a *well-argued point of view*.
- Is such a carrier bag really necessary? Do you know a better alternative? And why would that alternative be better?

5 Argumentation

The making of a choice includes giving an argumentation. In such an argumentation you explain why you choose the one alternative, and not the other.

- What do you have to pay attention to in presenting a *well-argued point of view* as clearly as possible?

6 Assessing an argumentation

Below you find an argumentation for the choice between two milk packages: the plastic returnable bottle and the carton. Read that argumentation first. Then answer the two questions about it.

> I choose the milk carton, because that is good for the environment. The milk carton is made of carton. This carton can be recycled: you can make recycled paper out of that.

- Is the content of the argumentation *correct*? Explain why it is or is not.
- Is the argumentation *complete*? Explain why it is or is not.

7 Decision-making procedure

In making a choice between packaging alternatives you take a number of steps. Those steps are (in arbitrary order): *making a choice*, *generating alternatives*, *monitoring developments*, *developing criteria*,

identifying decision-making situation, *comparing alternatives*. By taking these steps in a specific order, you follow a *decision-making procedure*.

- Draw a scheme of that *decision-making procedure*: put the steps in the right order, and indicate how they are connected to each other.
- On which *environmental criteria* do you compare the packaging alternatives in that decision-making procedure?
- Which *kind of knowledge* do you need for being able to compare the packaging alternatives on those environmental criteria?

Figure 6.23 – End-of-unit content test.

Learning effects

The results of the content test concerning the unit's learning effects with respect to the students' *issue knowledge* and *decision-making skill*, and their perception of the *decision-making procedure* could be summarised as follows.

Issue knowledge – Without going into much detail, it can be concluded that the students' answers to the questions about reasons for packing products, environmental problems related to packaging and solutions for these problems (questions 1 and 2) are reasonably correct and complete. However, this only concerns the students' *general* issue knowledge. It was expected that part of the remainder of the content test (questions 4 and 6) would provide some data on their *specific* issue knowledge in terms of the criteria-related properties of packages and packaging materials. This expectation, however, did not come true as a result of the considerable difficulty the students appeared to have with a systematic reproduction of the comparison of the packaging alternatives on the environmental criteria – a difficulty which will be further addressed below.

Decision-making skill – In identifying a decision-making situation (question 3) the large majority of students refers to the familiar example of the milk bottle and carton. In response to the second part of the question a small majority of the students expresses that, in order to be able to make a choice, knowledge is needed about the contribution to depletion and pollution of the packaging materials concerned. Very few students only mention either depletion or pollution. Roughly half of all these students also indicate that knowledge about recycling these materials is needed, although they do not explicitly do so in connection to the impact of recycling on depletion and pollution. Finally, some students only mention the need for knowledge about recycling.

The presentation of an argued point of view in the given decision-making situation about a plastic/paper carrier bag (question 4) shows disappointing results: a large majority of the students only addresses the preferred alternative on one and incidentally both environmental criteria, or addresses both alternatives on one criterion only. Comparing both alternatives on both criteria is rarely done: by 3 out of 23 students only. It must be concluded that only in a very small number of cases the argued point of view includes a systematic reproduction of the comparison of both

alternatives on both environmental criteria. This reflects the lack of development of a *presentation standard* in the course of the teaching/learning process. As no such standard has been developed and established, it cannot be expected that the students' argued points of view in the content test would meet this intended standard.

Considering the disappointing results of the test's previous question, it does not come as a surprise that identifying the points to pay attention to in clearly presenting an argued point of view (question 5) appears to be difficult for the students. Somewhat less than half of the students indicates that one has to say 'something' about depletion, pollution and or recycling, without specifying to what this 'something' relates. An even smaller number of students indicates that the argumentation should contain comparisons, either on 'all points' or the environmental criteria. And incidentally it is mentioned that the argumentation's content should be correct. Their assessment of a given argumentation on these points (question 6) therefore also lacks completeness: most students indicate that the given argumentation does not explicitly address depletion, or pollution, or the other alternative, but combinations of these three lacking elements in their answers to this question are scarce. It must be concluded that the difficulty students have with presenting an argued point of view in a relatively simple decision-making situation about packages (plastic or paper carrier bag) is also reflected in the more demanding tasks of reflecting on such a presentation.

Decision-making procedure – At the end of the test roughly half of the students is able to reproduce the decision-making procedure (question 7), although including the step of 'monitoring developments' presents them with quite some difficulty as its meaning has not been sufficiently addressed in the unit. An ample majority of the students mentions depletion and pollution as the environmental criteria, and to a slightly lesser extent they now describe the kind of knowledge necessary for comparing packaging alternatives correspondingly as knowledge about their contribution to depletion and pollution. The difference with their answers to the earlier question 3 about packaging decision-making situations might be explained by its more open character.

Conclusion – From the content test data it might be concluded that the still disappointing learning effects concerning the presentation of an argued point of view are in line with the observed stagnation of the teaching/learning process in the unit's application phase.

6.10 Conclusion

The findings presented in this chapter can be summarised by considering the following two general questions: has the elaboration of the didactical structure resulted in a 'good enough' teaching/learning process, and has the preparation of the trial teacher been 'good enough' for adequately guiding the students through this process?

Teaching/learning process

The overall conclusion to be drawn from the empirical data and their evaluation in the preceding sections 6.3 up to and including 6.9 is that the elaboration of the didactical structure in terms of the scenario and student materials is not yet 'good enough' for practical purposes. This mainly concerns the scenario, and to a far lesser degree the student materials. Apart from the necessary fine-tuning of the scenario for keeping the teaching/learning process on-track, a considerable revision is needed concerning those instances where the teaching/learning process clearly comes to a standstill. That is, those instances where the scenario addresses the purpose and teaching procedure of the tasks aimed at a development and explicitation of a content and a presentation standard in the unit's application phase. And, apart from minor modifications of some tasks in the student materials, the reference materials used by the students during the investigation phase are in need of a revision concerning the students' pre-knowledge about pollution through dumping and burning packaging waste. The character of the necessary fine-tuning and revision, however, does not point at *structural* design errors such as the ones identified in the unit's first version during the preceding cycle of developmental research.

The observation and evaluation of the classroom trial have yielded enough ideas for the necessary fine-tuning and revision of the scenario and student materials, and an associated appropriate teacher preparation. It can be expected that implementing these ideas would be enough to prevent the identified stagnation of the teaching/learning process. That is, the fine-tuned and revised scenario and student materials can be expected to be 'good enough' for teaching practice, and could therefore be tested on a larger scale.

Teaching style

The preparation of the teacher on the trial of the unit's second version has been described in chapter 5 (section 5.5). A main issue in this preparation was the teacher's didactical practice concerning conducting and guiding whole-class discussions and making explicit the global and local teaching/learning process. What has been the result of this preparation?

Whole-class discussions – In conducting and guiding the whole-class discussion in the motivation phase of the unit the teacher seems to show some inflexibility in taking the scenario's 'prescriptions' as just a rough guideline. As this phenomenon only occurs in the unit's first phase, it might be explained by a kind of 'beginner's insecurity' when teaching something new. In comparison to the first trial, the teacher now seems to be better able to limit himself to further questioning based on what the students are putting forward and to structuring the discussion. Of course, there are still instances of a too hasty interpretation of the students' reactions, of being too dominant and of missed opportunities for further questioning. But these instances occur less frequent than has been the case during the first trial.

There are, however, three instances in which the teaching/learning process really goes off-track. The first of these three instances relates to the summoning of ques-

tions for further investigation in a decision-making context in the question phase of the unit (task 7 up to and including 9). At this point the teacher refrains from the necessary further questioning in order to raise doubts about the students' seemingly unanimous comparisons of packaging alternatives. This can be seen as a temporary misperception of the task's purpose and connected teaching procedure, as those were both clearly described in the scenario. The second instance is when students clearly start having doubts about the credibility of the information in the reference materials during their presentations in the application phase of the unit (task 16). The teacher has not been able to solve this unexpectedly emerging problem at the spot. However, this clearly represents a flaw in the scenario and the reference materials as indicated earlier, and can neither be 'blamed on the teacher' nor on an inappropriate teacher preparation. Roughly the same goes for the third instance concerning the stagnation of the teaching/learning process in the application and reflection phases of the unit. As has been stated earlier, at these points the scenario lacks a clear enough description of the tasks' purposes and connected teaching procedures.

The conclusion can be that the teacher's didactical skill of guiding the whole-class discussions has improved considerably as compared to the first trial. This could be seen as a positive result of the additional preparatory element of the teacher's reflection on his own classroom practice during the first trial.

Explicit teaching/learning process – Far more than during the first trial, the teacher appears to be aware of the importance of making explicit the global teaching/learning process. The teacher is looking back and forward at the global teaching/learning process at the appropriate moments (the transitions between the unit's phases), and tries to engage the students in this activity. Moreover, at those instances where the coherence of the global teaching/learning process seems to be lost as a result of the emergence of problems not foreseen in the scenario, he succeeds in making the best out of it.

Making explicit the local teaching/learning process, however, still appears to be more difficult. On a number of occasions the transition from one task to the next is either lacking or dealt with in a still unsatisfactory way – unsatisfactory in the sense of either not really connecting to what did happen in the previous task or not giving a preview on the next task in a way that can be understood by the students. As paying explicit attention to the local teaching/learning process is not a common element in traditional teaching, the teacher's difficulty in doing so is quite understandable. It must be further noted that during the preparation on the second trial the teacher has already expressed some doubts concerning his ability to put this into practice.

The conclusion must be that with respect to making explicit the local teaching/learning process in the intended way the preparation of the teacher on the classroom trial is not yet 'good enough'. More training and more feedback on the teachers' classroom practice concerning this unfamiliar and difficult task are needed.

7 Reflection

7.1 Introduction

In chapter 1 two broad motives for undertaking this study were presented, giving rise to the general research question to be addressed. The purpose of this final chapter is, first of all, to reflect on this general research question: to what extent has the problem of a lacking interpretation of the attainment target about decision making been solved, and to what extent could the chosen starting-points for designing the teaching/learning process be considered adequate for having the students reach this attainment target? Secondly, the purpose of this chapter is to reflect on the character of the topic-specific didactical structure and to explore its potential for further developmental research in the area of students' decision making about other science/technology-related social issues and in the even broader area of skill development other than decision making.

This chapter will start off in sections 7.2 and 7.3 with a discussion of what this study did yield in the light of each of the two broad motives for undertaking it, consecutively dealing with an interpretation of the attainment target about decision making and with the adequacy of the starting-points for designing the associated teaching/learning process, including some reflections on the teacher's learning. Section 7.3 is concluded with a summary of the answers to the specific research questions formulated in chapter 2. So, up to this point the chapter will be dealing with a reflection on the *product* of the developmental research described so far in this study: a topic-specific didactical structure for the teaching/learning about decision making on the waste issue. In section 7.4 it is tried to address the question of the didactical generalisability of this product by presenting a generalised didactical structure in terms of distinct levels of knowledge and skill and of a sequence of a number of distinct teaching phases each having a specific didactical function. The chapter concludes in section 7.5 with some speculations about the applicability of such a generalised didactical structure in further developmental research concerning the teaching of decision making and other complex intellectual skills such as problem solving.

7.2 The attainment targets

The first broad motive for undertaking this study as expressed in chapter 1 reflected the issue of tuning conceptual science knowledge to everyday life decision-making situations in which it has to be used productively, and the operationalisation of the

attainment target about decision making. The question to be addressed now is what this study did yield in this respect. An answer to this question could be seen as the first product of the didactical research presented in this study.

Content and presentation standards

First of all, the study has shown that – different from what was intuitively thought in the phase of exploratory research and development as described in chapter 2 – students of the specified age and ability level at this point in the junior secondary physical science curriculum have sufficient knowledge about the general structure of the environmental issues concerned in order to be able to identify the relevant environmental criteria for decision making. However, for each of these environmental issues the students have to first extend their specific, criteria-related issue knowledge in order to be able to arrive at an argued point of view of sufficient quality in related decision-making situations. That is, an argued point of view that meets the *content standard* introduced in the previous chapter. Meeting this content standard is not possible without a sufficient body of issue knowledge.

Secondly, the study has shown that the students are familiar with a decision-making procedure in terms of its basic elements of comparing alternatives on criteria and weighting of the comparisons made in order to reach a decision. However, the study has also shown that – again different from what was intuitively assumed previously – arriving at an argued point of view in such a way does not automatically lead to a presentation of sufficient quality. That is, a presentation of an argued point of view that meets the *presentation standard* introduced in the previous chapter. Meeting this presentation standard would result in a clear, systematic and explicit reproduction of the constitutive elements of the decision-making procedure.

If the students use both standards not only in their own argumentation, but also in their reaction to the argumentation of others, it can be said that the attainment target of being able 'to present an argued point of view in a decision-making situation' did get a meaningful operationalisation. This is not to say, however, that this aim has been reached during the teaching/learning process featuring in this study – as has become apparent in its evaluation in the previous chapter. It would be better to say that this aim has gradually emerged during this evaluation. And an additional remark should be that it is questionable whether such an aim could be reached within one limited series of lessons such as the one in this study. As stated earlier in chapter 1, the waste issue could be seen as a suitable topic to *start* tackling the attainment target about decision making. Reaching this target in the above-described sense would then be a process of gradually making progress when subsequently dealing with other science/technology-related social issues.

In the light of the above-described operationalisation of the attainment target about decision making, it can be said that the NME-VO project's units as well as other teaching/learning materials discussed in chapter 2 quite logically represent a still rather weak attempt at doing so, as they do not pay any or enough attention to

introducing and handling the tool of a stepwise decision-making procedure, and do not aim at developing and making explicit a content and a presentation standard for an argued point of view. Concerning these weaknesses this study has led to an increased didactical insight, based on concrete classroom practice, about what could or should be meant with this attainment target and the way in which it could or should be reached.

After having achieved this, it could be seen as a disappointment that the attainment target under consideration did not – at least at first sight – survive the recent revision of the programmes for all the school subjects in junior secondary education …

Revised attainment targets

In the revised physical science programme (OCW, 1998) decision making has been removed from the skills domain. It has 'returned' as one of the elements in one of the *general aims* of physical science at this level of education, stating that students are to "acquire knowledge and skills in the area of physics and chemistry with a view to decisions about continued education, future professional practice and social functioning". This last mentioned element could be interpreted as a remnant of the original attainment target about decision making in the skills domain. It is unclear whether or not this interpretation is correct, and what the status of these general aims is supposed to be. It has therefore – contrary to what clearly could be assumed previously – become a matter of programme interpretation whether or not decision making should be a distinct feature of the curriculum.

The same programme revision has 'upgraded' the attainment targets about environmental issues by awarding them a new, distinct knowledge domain labelled 'nature and environment'. The (single) attainment target in this domain states that students are to be able "to connect the use of water, cleaning agents, cosmetics, energy and sound as specified in the preceding attainment targets, to nature, environment and sustainable development". It is striking that this attainment target does not mention decision making, that only some of the preceding attainment targets it refers to mention 'pros and cons of …' or 'making a choice between …', and that – although the attainment targets about the waste issue are still present and unchanged – this issue no longer seems to be considered as connected to 'nature, environment and sustainable development'.

Maybe the reasons for these recent changes have to do with the problem of how to operationalise the original attainment target about decision making mentioned in chapter 1. This problem then has been 'solved' by 'hiding' it in the general educational aims. However, the reason for revising the attainment targets in the above-outlined way might also have to do with a growing tendency to see 'scientific and technological literacy' as one of the general aims of science and technology education at the secondary level (e.g., Layton, 1994; Yager, 1996; Millar & Osborne, 1999; Eijkelhof, 1999). This education for scientific and technological literacy might be seen as a follow-up to the STS education sketched in chapter 1. In general

such an education should "enable students to deal effectively with socio-scientific issues which incorporate scientific, political, ethical, social, technological and environmental dimensions" (Ratcliffe, 1999). Without yet being able to pinpoint a clear and all-encompassing definition of scientific and technological literacy, it could certainly be said that being able to 'talk sensibly' about personal and social issues involving scientific and technological knowledge would be one of the constituting elements. If this is correct, the former attainment target about decision making could still be seen as a partial and still general operationalisation of such literacy. The results of this study could then be seen as a more specific operationalisation, useful for developing a decision-making strand in the physical science curriculum for junior secondary education. This would then mean that in practice, although it seems that the programme has changed considerably, maybe nothing much has changed.

7.3 A topic-specific didactical structure

The second broad motive for undertaking this study as expressed in chapter 1 did concern the need for an empirically supported design of an adequate didactical structure that describes how the attainment targets about the waste issue and decision making may be reached in classroom practice. The question to be addressed in this section is what this study did yield in this respect. An answer to this question could be seen as the second product of the didactical research presented in this study.

A problem posing approach

The core of a problem-posing approach to the teaching/learning about a specific topic has been described earlier as "an approach whose emphasis is on bringing pupils in such a position that they themselves come to see the *point* of extending their existing conceptual resources, experiential base and belief system (with accompanying changes of meaning) in a certain direction" (Klaassen, 1995, p. 111). For the topic under consideration a first step in this approach has been the didactical structure as described in chapter 3 (section 3.4) and visualised in figures 3.4 and 3.5. The developmental research described in chapters 5 and 6 did yield indications for a necessary fine-tuning and revision of the scenario.

An incorporation of these ideas results in a 'final' didactical structure, the core of which is the interrelated development of environmental issue knowledge and the skill to use this knowledge in related decision-making situations. More specifically, a problem-posing approach requires that students are provided with and (further) develop content-related motives to make their learning process make sense to them. This motives-driven interrelated development of knowledge and skill is summarised below in figure 7.1. The three-column scheme shows how the teaching/learning process switches between issue knowledge and decision-making skill, and that these

switches seem to come rather naturally forward because of the content-related motives that are developed.

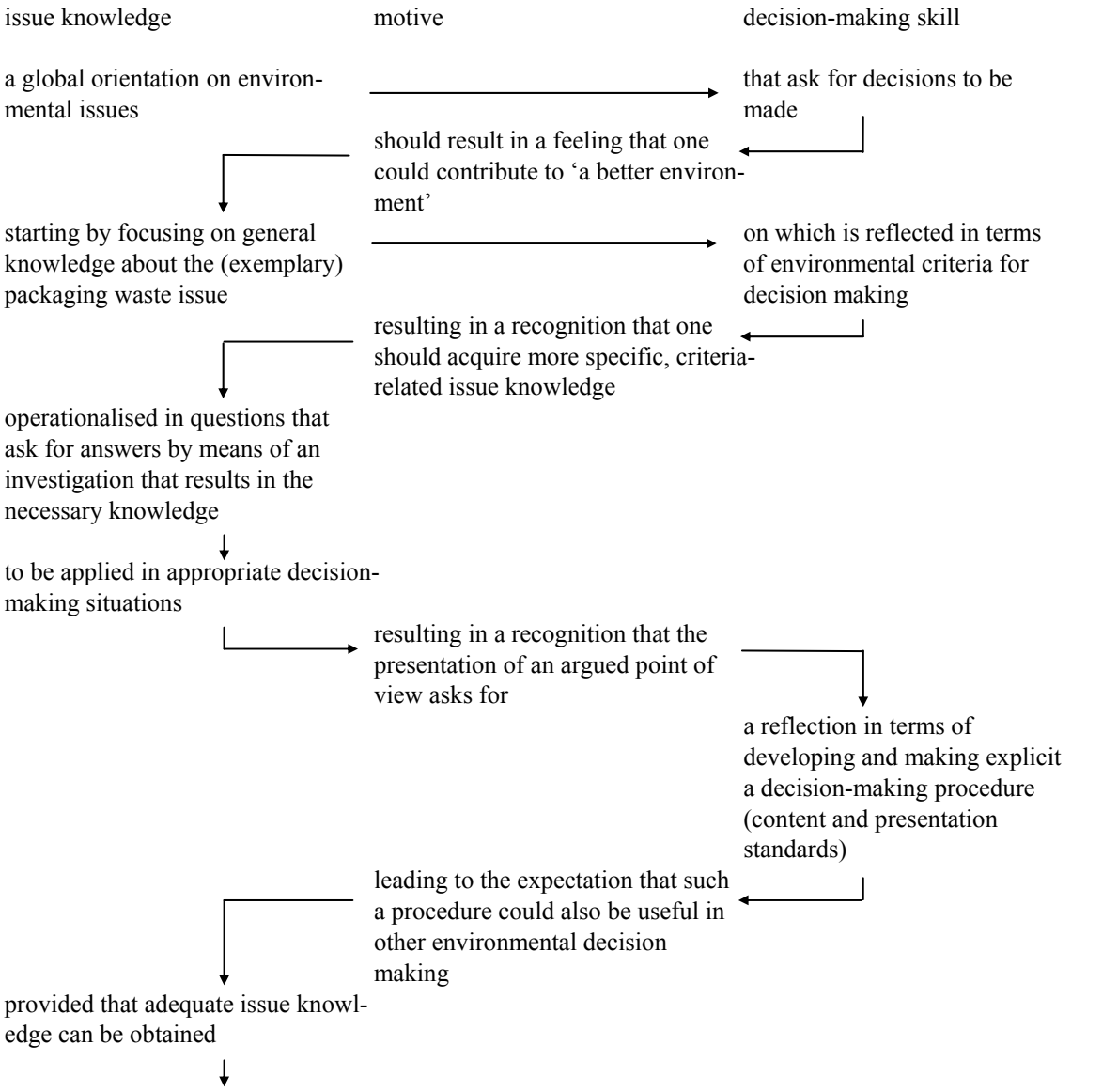


Figure 7.1 – A summary of the didactical structure for a problem-posing approach to the teaching/learning about decision making on the waste issue.

This didactical structure reflects the main content-related steps to be taken in teaching about the topic of decision making on the waste issue as an example of an environmental issue, as well as the interrelatedness of two teaching processes focused on learning to present an argued point of view. The development of a content and a presentation standard shows how the skill of being able to present an argued point of view crucially depends on having available sufficient knowledge to

compose the argumentation to be presented, while, at the same time, this knowledge is acquired in view of this argumentation. These seem to be important differences with the few other attempts to incorporate decision making in science education at classroom level, such as the one by Ratcliffe (1994; 1997; 1999). In her approach a decision-making task with an explicit general structure (roughly comparable to the decision-making procedure discussed in chapter 3) was 'tacked on' to a number of existing teaching/learning units that contained some information helpful to the decision-making process. It was left to the students to identify criteria, to generate alternatives and to use the unit's contents for comparing the generated alternatives on the identified criteria. One of the conclusions drawn from her case study research is the obvious one that awareness and use of relevant information contributes to thoughtful decision making. But she also concludes that the links to the available science knowledge are not obvious to the students, and that most of them need (more) specific prompting to encourage them to identify and use this knowledge (Ratcliffe, 1997). A far more 'natural' way of linking the development of issue knowledge and decision-making skill is to make the decision-making context explicit right from the start, and to have the students first recognise the need for acquiring specific issue knowledge with respect to the required decision making – as has been tried to do in this study. For in this way, the students then know why this knowledge is being acquired by them.

Extrapolation – In the teaching/learning unit based on our didactical structure, the focus on decision making is operationalised as 'being able to present an argued point of view about the waste issue'. The procedural heuristic rules that are to emerge from reflection on actual presentations of an argued point of view, are thus still contextualised. A first extrapolation can take place when these procedural rules are extended to 'presenting an argued point of view about other environmental issues'. This represents a curriculum focus, in which this skill is developed gradually, as already mentioned in section 7.2 and indicated in figure 7.1. A further step regarding this skill could then be made by changing the focus from 'presenting an argued point of view' towards 'decision making as a topic in itself'. By a reflection on the contextualised procedures, a decontextualised set of heuristic rules may be formulated that may function as a tool for decision making in rather complex situations. Or, in other words: as a meta-cognitive tool that helps to regulate and control the cognitive steps to be taken in such a process (Boekaerts & Simons, 1993).

This brief sketch of a stepwise and content-embedded approach towards the teaching of the 'general skill' of decision making may possibly be extrapolated to the teaching of other skills as well, as will be further discussed in section 7.5.

The starting-points

Now we may ask whether our confidence in the value of the chosen didactical starting-points for our approach has been strengthened in view of what has been achieved. A first starting-point, as indicated in chapter 3, has been the adoption of

'educational constructivism' as summarised by Ogborn (1997, p. 131) in the following way:

- The importance of the pupils' active involvement in thinking if anything like understanding is to be reached.
- The importance of respect for the child and for the child's own ideas.
- The design of teaching should give high priority to making sense to pupils, capitalising and using what they know and addressing difficulties that may arise from how they imagine things to be.

From the description of the scenario it should have become clear how these main points have been dealt with. In retrospect, it can also be said that we did operationalise a moderate social-constructivist view of learning (Duit & Treagust, 1998), which could be characterised by an (additional) emphasis on the necessity of classroom interaction if learning is to take place. In our teaching scheme this is reflected by the inclusion of collaborative group work (Van Boxtel, 2000), followed by whole-class discussions of teacher and students. Though we have to admit that, in classroom practice, this social interaction did not always proceed as intended, we do think that students were provided with sufficient opportunities to bring forward their ideas and to build on them interactively in a productive way. In our approach we have, in fact, adopted a strategy which comes close to what has become known as 'guided construction/discovery' or 'guided reinvention' (Driver, 1989; Freudenthal, 1991; Gravemeijer, 1994). In this respect, we can point at our attempts to actively involve students in a gradual explicitation and extension of their knowledge and skill. Even though this has not been a complete success as far as developing a content and a presentation standard for an argued point of view is concerned, there is no reason to doubt the position taken. We would like to stress, however, the need for a proper interpretation of students, in this case of their existing issue knowledge and decision-making skill. In fact, we think that the emphasis of much conceptual change literature (cf. Hewson *et al.*, 1998) on the need for changing instead of extending students' existing conceptions, by means of conflict strategies or otherwise, is a result of misinterpreting them.

The second starting-point mentioned in chapter 3 did concern the intention of designing a *problem-posing* teaching/learning process. This intention seems to have been adequately elaborated as far as the students' issue knowledge is concerned. In the context of a general motive related to decision making about environmental issues, the students' everyday life issue knowledge has been problematised successfully, which has provided them with a more specific motive for extending their issue knowledge and applying their extended knowledge. What has not been achieved so far is, in similar terms, a problematisation of the students' everyday life skill of presenting an argued point of view that would have provided them with a more specific motive for developing an explicit standard for such a presentation. A standard that would serve as a meta-cognitive tool for structuring and assessing the quality of their own and their fellow students' presentation of an argued point of view. In retrospect, it must be said that the necessary problem-posing character of

the teaching/learning process with respect to such a development of the students' decision-making skill still leaves to be desired.

The teacher's learning – Designing a problem-posing teaching/learning process asks for something quite different from the usual writing of a – in the eyes of the one who writes – logical, content-dominated story with associated suitable exercises for the students as identified in chapter 2. The problems associated with this required paradigm shift with respect to curriculum development will be further discussed in section 7.5. However, a paradigm shift was not only needed with respect to curriculum development, but also with respect to testing its product by the teacher. Instead of 'retelling the story' and 'presenting the correct answers' what was asked from the teacher by the scenario was something quite different: to adequately structure whole-class discussions, to listen carefully and to interpret properly what is being put forward by the students, to make the global and local teaching/learning process explicit and to continuously keep watch over its coherence. In both trials at times the scenario seems to act like a 'strait-jacket' for the teacher. There were instances of classroom practice where the teacher is trying to follow the scenario's 'prescriptions' too narrowly. In those instances the students might have perceived their input into the teaching/learning process as wrong or as not taken seriously – which is not at all intended to be the case. However, in those instances where the teacher seemed to 'forget' the scenario the teaching/learning process quickly went off-track. This suggests that the scenario is necessary for pre-trial preparation and actual teaching practice. The inflexibility induced by the scenario can probably only be dissolved by the teacher's learning from (further) reflected classroom practice.

Teachers have their life-long habits and their implicit, intuitive practice-based theories about 'what works and what doesn't' in classroom practice with their students. Changing these habits and ideas when this is required by 'new' ideas about teaching/learning – such as a problem-posing approach – is difficult for teachers, and most probably will not be reached through a traditional teacher-training approach in which an expert teaches theoretical knowledge to prospective teachers and – in the best case – stimulates the transfer of this knowledge to the classroom (Bullough & Gitlin, 1994). Although such a traditional 'application model' is widely used, the 'transfer of theory to practice' is problematic (Wubbels *et al*., 1997). More promising approaches "can be characterised by an emphasis on reflective teaching (Calderhead, 1989), implying that teacher development is conceptualised as an ongoing process of experiencing practical teaching and learning situations, reflecting on them under the guidance of an expert, and developing one's own insights into teaching through the interaction between personal reflection and theoretical notions offered by the expert" (Korthagen & Kessels, 1999, p. 6). Although the setting in the developmental research in this study is quite different, the teacher's preparation on the classroom test of the teaching/learning unit could be considered as some sort of 'in-service teacher education course'. What has been done in this 'course' at least reflects some of the identified critical features for successful in-service teacher education that most frequently appear in the literature

(Joyce & Showers, 1988): an explanation of the theoretical underpinning of the approach (in this case: a problem-posing approach to teaching/learning), a demonstration of the approach by an expert (in this case: the detailed scenario describing intended and expected classroom practice), and using the approach in school together with coaching in the school (in this case: a reflection on instances of good and not-yet-so-good classroom practice). This clearly includes the desired expert-guided reflection of the teacher on his own teaching practice, although this activity has been carried out by the 'expert' in a probably too directive way, with an incomplete use of available instruments and with a lacking focus on 'developing theory from practice' as compared to what might be considered desirable (Korthagen & Kessels, 1999; Korthagen, 1999).

Didactical criteria – After having described the main results in terms of increased didactical knowledge about the attainment targets and about how to teach and learn them, it may be informative to also relate this study to that of Alblas (1999), who formulated a set of didactical criteria that are supposed to ensure the quality of teaching/learning processes in environmental education. Without going into any detail about the way in which the didactical structure reflects each of his distinct didactical criteria, it can be said that it complies with the two identified main categories of 'personal closeness' and 'exemplarity' (Alblas, 1999, pp. 268-269). In teaching/learning processes this personal closeness is characterised by "the students' active approval of the content and objective of the learning process" and the usability of its content in a social context. Making the students recognise the need for acquiring specific issue knowledge in a perspective of personal environmental decision making could certainly be seen as an operationalisation of the didactical criteria making up this first main category. The second main category of exemplarity relates to "going back and forth […] between concretisation and abstraction" and symbolising knowledge in one way or another. The didactical structure clearly starts at a rather concrete level of personal environmental decision-making situations and gradually builds up to abstract and schematically visualised knowledge about a decision-making procedure, to be used in tackling other concrete environmental issues (be it in follow-up series of lessons).

Thus we may conclude that our didactical structure, both in its starting-points and details, relates very well to the criteria for 'good environmental education', even though both studies have been done independently. At the same time our study shows that having available a set of general didactical criteria is no guarantee for an easy and straightforward process of designing a didactical structure that is 'good enough' for teaching practice.

Research questions

Now, before going into further speculations about the characteristics and possible value of our approach, we first want to summarise the answers to the specific *research questions* about an adequate body of *issue knowledge* as a conceptual input into an adequate *decision-making procedure*, a proper interpretation of the students'

pre-knowledge and decision-making skill, a good enough bottom-up *teaching/learning process*, and an adequate *teacher preparation* that were posed in chapter 2.

Issue knowledge – What constitutes an adequate body of waste issue knowledge as conceptual input into the students' decision making?

In chapter 3 it was stated that an obvious answer to this first specific research question would be: knowledge about the *environmental criteria* (depletion and pollution) and about *criteria-related properties* of packages and packaging materials. There is no reason to doubt that this body of waste issue knowledge is adequate for decision-making purposes. However, acquiring part of this body of knowledge in classroom practice was shown to be somewhat problematic as a result of incompletely connecting to the students' pre-knowledge about pollution through dumping/burning of household waste.

Decision-making procedure – What constitutes an adequate procedure for the students' decision making, and could it be made explicit by them?

An answer to the first part of this second specific research question was assumed to be the decision-making procedure as modelled in figure 3.3. Classroom practice has shown that the chosen procedure is adequate indeed: the students have no difficulty in working through the procedure's consecutive steps in those tasks where the format of the task implicitly represents this procedure. Moreover, in those tasks where using this procedure would be appropriate, the students, without being explicitly told to do so, do indeed do so. In chapter 3 it was further assumed that having the students make this procedure explicit would be possible by asking them to reflect on their decision-making experiences. Classroom practice has shown that the students are able to do so, be it under some 'guidance from above' by a puzzle format of the reflection task. It must be noted, however, that this only concerns the visualisation of the decision-making procedure, and not an explicitation of content and presentation standards for an argued point of view.

Pre-knowledge and decision-making skill – What constitutes a proper interpretation of the students' pre-knowledge about the waste issue and their decision-making skill?

Answers to this third specific research question are closely related to the questions about an adequate body of issue knowledge and an adequate decision-making procedure. In chapter 3 it was assumed that a proper interpretation of the students' pre-knowledge about the waste issue would be that students are knowledgeable about the *general structure of the waste issue* as outlined in figure 3.2. Classroom practice has shown this interpretation to be largely correct. If this interpretation had not been correct, the students would not have been able to analyse the analogy between selected personal environmental decision-making situations, would not have been able to construct the model of the waste issue with a minimum of preparation, and would not have been able to identify the environmental criteria relevant for decision making about packages from it.

In chapter 3 it was further assumed that a proper interpretation of the students' existing decision-making skill would be that students are – consciously or intuitively – knowledgeable about a criterion approach to decision making, and thus susceptible to decision making along the lines of the adopted decision-making procedure. As already stated earlier when discussing the adequacy of the chosen decision-making procedure, this interpretation has appeared to be largely correct. And finally, the estimation of the students' lacking pre-knowledge has also been shown to be largely correct, as the students' initial comparison of packaging alternatives on the established environmental criteria does indeed trigger questions for further investigation about criteria-related properties of packages and packaging materials.

Teaching/learning process – What constitutes a good enough bottom-up teaching/learning process for decision making about the waste issue?

Also this fourth specific research question was tentatively answered in chapter 3: a *problem-posing* teaching/learning process as summarised by figures 3.4 and 3.5. In this teaching/learning process the students' existing motives, issue knowledge and decision-making skill were supposed to productively drive their learning process. Though the problem-posing character of the teaching/learning process seems to have 'worked' to quite some extent, some more work has to be done in solving the stagnation near its end as identified in chapter 6. These deficiencies in the scenario seem to be detrimental to the coherence of the teaching/learning process.

Teacher preparation – What constitutes an adequate teacher preparation for implementing the designed bottom-up teaching/learning process in classroom practice?

In chapter 3 the answer to this final specific research question was assumed to be: to read and discuss the scenario and student materials, as these give a quite extensive description of the intended and expected classroom practice. It appeared, however, that teaching practice left to be desired with respect to conducting whole-class discussions (including the interpretation of what was being put forward by the students) and making the global and local teaching/learning process explicit. Therefore, reading and discussing the scenario has been supplemented with a reflection on selected instances of the teacher's own good and not-yet-so-good classroom practice. In the second trial this additional pre-trial reflection appears to have been useful to quite some extent by contributing to a growth of the teacher's understanding of the required changes in teaching style and his self-confidence with respect to the ability to teach in this way.

7.4 The structure of the didactical structure

The previous section mainly focused on content-related aspects of the 'final' didactical structure. In this section we will speculate about the *didactical generalisability* (Lijnse, 2000) of what we have learned so far. This discussion will focus on two main aspects: *level structure* and *teaching phases*.

Level structure

A first step towards generalisation is made when we ask ourselves whether the characteristics of the didactical structure of figure 7.1 could be formulated, in a still useful way, in content-independent terms. The scheme of figure 7.2 tries to do so, resulting in a *problem-posing, level-structured didactical structure*.

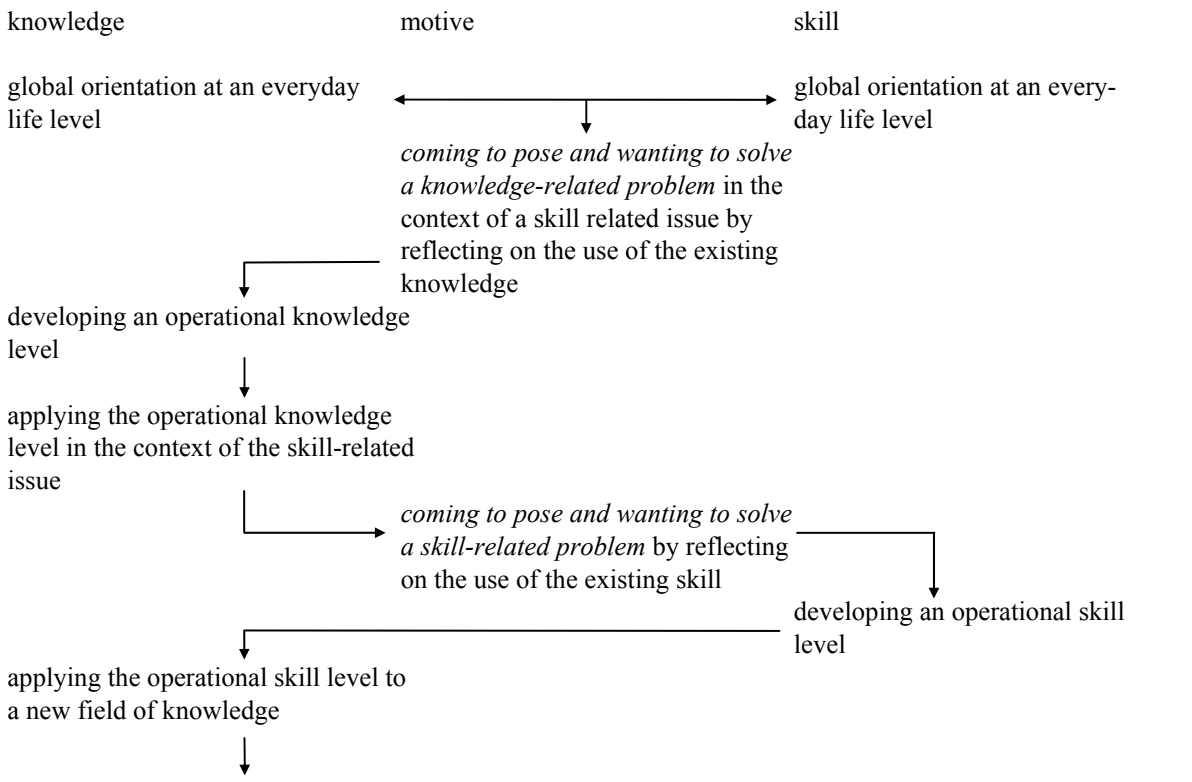


Figure 7.2 – A summary of a problem-posing, level-structured didactical structure for the interrelated teaching/learning of knowledge and skill.

The scheme shows, again, the coupling between the two interdependent learning processes of knowledge and of skill, or the intended interrelated development of students' cognitive and meta-cognitive abilities. Both learning processes have been formulated in terms of two consecutive levels, indicated as an *everyday life level* and an *operational level*, respectively. The use of these labels implicates that this generalised didactical structure is restricted to teaching/learning processes within a *practical* orientation. That is, processes starting from practical problems inherent in everyday life situations that ask for a solution.

Everyday life level – At the everyday life level the students' (assumed) motive is their willingness to tackle a practical problem, while their knowledge needed for solving this problem is still incomplete and weakly structured, and their skill consists of a still intuitive procedure – a mixture of 'bits and pieces' picked up

through everyday life experiences, ‘things’ that students know and are able to do without having been explicitly taught to know and do.

Operational levels – The operational knowledge-level is characterised by a structured and complete body of practical knowledge sufficient for actually solving the practical problem introduced at the start of the teaching/learning process. An operational skill-level can be defined in the sense that students have available a set of procedural heuristic rules, according to which they can regulate and control their skilful behaviour. As said before in section 7.3, having reached this level means that students have got available an explicit meta-cognitive tool.

While the everyday life level indicates the starting-point, the operational levels for knowledge and skill indicate a useful endpoint of the intended learning processes in terms of relevant concepts and skill. That is, relevant for better understanding or even solving the practical problems introduced at the start. For both learning processes, the transition between the respective levels is triggered by the posing of a problem that the students themselves want to solve, and that thus provides them with a motive that further drives their learning process. Or, in other words: the transitions are triggered by reflectively problematising the students’ existing knowledge or skill. In case of a problem-posing approach, this involves bringing students in such a position that, guided by the design of the teaching/learning activities, preferably they themselves come to pose a problem that makes them see the need for extending their knowledge and/or skill. The way in which this is reached could therefore be considered the ‘core’ of such an approach.

Teaching phases

A second feature of the scheme in figure 7.2 is that the teaching process according to which the transitions between the respective levels is supposed to take place, can be divided into several phases, each of which has a specific didactical function. In the literature on instruction, several attempts have been made to formulate such phases as an instrument to improve instructional designs. Well known are the so-called ‘learning cycles’ (Abraham, 1998), described briefly as ‘inform, verify and practice’ in the case of a more traditional view on teaching, and as ‘explore, invent and apply’ in the case of a more inquiry-based view on teaching. Both apply in the first place to the teaching of concepts. Other, more extended descriptions are given by Ten Voorde (1977, 1980) and by Driver & Oldham (1986). The first, inspired by a level scheme originally developed for mathematics education (Van Hiele, 1986), distinguished five teaching phases of ‘information, bounded orientation, explicitation, free orientation and integration’, meant to describe a teaching process that enables students to make the, in his view, necessary level transitions. The latter designed a ‘constructivist’ teaching strategy that consists of a sequence of ‘orientation, elicitation, restructuring, application and review’.

These strategies all differ from our problem-posing approach in important aspects, such as the attention paid to developing content-related motives that drive the students’ learning process and the status and productive use of their existing

knowledge and skill. In a problem-posing approach, as given in figure 7.2 for the teaching of one topic only, we may distinguish the following six phases:

- Phase 1: orienting and evoking a global interest in and motive for a study of the topic at hand.
- Phase 2: narrowing down this global motive into a content-specific need for more knowledge.
- Phase 3: extending the students' existing knowledge, in view of the global motive and the more specifically formulated knowledge need.
- Phase 4: applying this knowledge in situations the knowledge was extended for.
- Phase 5: creating, in view of the global motive, a need for a reflection on the skill involved.
- Phase 6: developing a (still possibly contextualised) meta-cognitive tool for an improved performance of this skill.

Phase sequence – The above outlined six-phase sequence has emerged from the attempt at developing a problem-posing approach to teaching the specific topic featuring in this study. However, when compared to other such attempts by Vollebregt (1998) and Klaassen (1995) there appears to be some similarity in this respect, thus giving the above-identified phase sequence a more general character. The first developed a problem-posing approach for teaching an initial particle model. This also involved two coupled learning processes, i.e., about the content of a particle model and about the nature of models in physics, but both within a to-be-developed theoretical orientation. Though she did not try to use a level-terminology, both the overall structure of her content-specific didactical structure and her phase-descriptions are to a large extent similar, though not identical, to those of the present study. In Klaassen's work on a problem-posing approach to teaching about radioactivity, only the teaching of conceptual knowledge within a practical orientation was involved. In his didactical structure we therefore recognise only the first four phases described above. In a more diffuse way, the same applies to the phases that are used by Janssen (1999) in his 'learning-by-designing' approach for biology education. From this brief comparison we may conclude that, with a view to further developmental research, it might be fruitful to come to a further characterisation and outline of a problem-posing approach for the teaching of, e.g., physics (or science) in terms of something like the above-given, tentative didactical terminology.

The above-outlined sequence of teaching phases slightly differs from the five teaching phases of 'motivation, question, investigation, application and reflection' as used in previous chapters. The first four of these five phases can be seen as topic-related operationalisations of the first four phases that are described above in more general terms. With this we mean that the second 'problem-posing' phase can result in the formulation of explicit questions for further investigation as in the present study, but that this is not a necessity – as is clear from Vollebregt's study. The same applies to the above-described third phase of 'extending knowledge'. If appropriate, this can be done by students' own investigations, but also in different ways as shown by Vollebregt and Klaassen. The difference between the reflection phase and the

phases 5 and 6 above, however, is of a more fundamental nature. In fact, this difference reflects our own didactical learning process.

In the didactical structure represented by figure 7.2 the step of 'coming to pose and wanting to solve a skill-related problem by reflecting on the use of the existing skill' is essential for reaching an operational skill level. For the teaching/learning process under consideration in this study this step relates to having the students come to realise their need for some kind of standard for the content as well as the presentation of an argued point of view on the basis of their decision-making experiences, and to consequently develop these standards. It is exactly at this point where the problem-posing character of the designed teaching/learning process leaves much to be desired, mainly as a result of a lack of clarity and procedural specification in the scenario. As a consequence, although the decision-making procedure is made explicit by the students themselves, it cannot be said that they have fully reached an operational level of decision-making skill in terms of presenting an argued point of view. By differentiating the original, rather vague reflection phase into two separate teaching phases, each with its own distinct didactical function, we think we have made some didactical progress.

Problem-based learning – It should be noted that the phases 2 and 5, in which the core of a problem-posing approach comes most directly to the fore, appear to be absent in the phase descriptions quoted from the literature so far. In this respect, also a brief comparison should be made with what has become known as problem-based learning. Although there is no universally agreed set of practices, the following features are characteristic of problem-based learning as an approach to education (Moust *et al.*, 1992; Boud & Feletti, 1997): the statement of a problem that challenges the students to think, activation of prior knowledge (since it is used in their thinking), the posing of questions by the students, a motivation to search for answers, co-operative learning, and guidance by a tutor.

The similarities with characteristics of our problem-posing approach are striking. The idea of problem-based learning, however, has originated within higher education, in which, as Van Aalsvoort (2000) remarks, it is elaborated in the framework of professional training of students. That is, students are supposed to be acquainted with the context of the profession of their choice, from which motives for learning may easily be derived. The situation in general secondary education, however, is quite different, especially with regard to this motivational aspect. Motives for learning physics hardly come naturally, and thus need to be created and maintained. That is precisely what we are aiming at, and from which the importance of phases 2 and 5 derives.

7.5 Developmental research

The level-structure of the didactical structure and the teaching phases identified in section 7.4 are expected to be useful for further developmental research concerning

a problem-posing approach to other topics in the physical science curriculum at the junior secondary level. Below, two distinct directions for such further developmental research are briefly explored: the teaching of *decision making* and of other *complex skills*. This exploration concludes with some reflections (or cautionary notes) on the element of curriculum development in this type of didactical research.

Teaching decision making

A first direction for further developmental research could be developing a *decision-making strand* concerning (other) environmental and non-environmental issues incorporated in the physical science curriculum at the junior secondary level. Some rough ideas about such a strand will be presented below, together with a cautionary note concerning the issue of the teacher's required *teaching style* in classroom practice and the consequences this might have for the necessary revision of the teaching/learning unit about the waste issue.

Decision making – The didactical structure for decision making about packages is meant as a starter for a decision-making strand in the junior physical science curriculum. The character of this didactical structure is such that it already prepares decision making about other environmental issues incorporated in the programme: the use of water and energy. By a reflection on their decision making about packages the students should have developed a meta-cognitive tool for an improved performance of this skill. All this could then be considered part of their pre-knowledge and skill, to be used productively in the follow-up units about other environmental issues. At some point these units might address the question whether or not the assumptions about the similarity of the environmental issues addressed so far are valid, and whether or not the meta-cognitive decision-making tool has been useful. From a research point of view it might be of interest to investigate whether this tool does indeed serve its purpose of facilitating students' decision making on new and complex issues. This has not been investigated in the study at hand, for the simple reason that it has only been concerned with an adequate way of *introducing* the tool.

At some point in this decision making strand of the curriculum the concept of sustainable development might be introduced, e.g. by reflecting on the similarity of the environmental issues (Kortland & Pieters, 1990; Kortland, 1992c). Also the social dilemma character of environmental decision making (Pieters *et al.*, 1998) might be explored to some extent at an appropriate moment. This means, simply put, addressing the question of 'what's the use of acting out an environmentally sound decision, as long as (all) the others don't'. This question is expected to emerge spontaneously at some point when dealing with personal environmental decision making situations, and then has to be addressed in one way or another – although not necessarily 'on the spot'.

Other issues in the junior physical science curriculum to which decision making might apply are noise and traffic safety. Addressing decision making on these other issues would mean developing and establishing a different set of relevant criteria.

Answering the question of what these criteria might be would require some further thinking …

Teaching style – Connected to the above-mentioned first direction of developmental research, one further issue has to be addressed. The topic-specific didactical structure for decision making about packages has been elaborated with a strong emphasis on classroom interactions between the teacher and the students and between the students among themselves. The students have to interact in order to summon and structure their shared pre-knowledge, to arrive at their questions for further investigation, to establish content and presentation standards for an argued point of view, etc. The teacher has to interact with the students to conduct these whole-class discussions and to make the global and local teaching/learning process explicit on the basis of what the students have been putting forward. What can be learned from the study at hand is that teaching in this way heavily calls on the teacher's ability to recognise and implement the required change of teaching style – maybe too heavily. This raises the question whether the amount of time spent on whole-class interactions should be reduced in favour of the students' working and learning independently. Moreover, such a shift in classroom practice would comply with the current tendency in Dutch education to emphasise the students' independent working and learning. This tendency at the moment is reflected mainly at the senior secondary level, but over time will probably percolate into junior secondary education as well. It has to be stressed, however, that the role of the teacher in a problem-posing teaching/learning process will remain crucial in terms of carefully providing adequate 'guidance from above', evenly balanced with the students' 'freedom from below'. Also this seems to be in line with the above-mentioned tendency in Dutch education, as the proposed change aimed at stimulating the students to work and learn independently has never been intended to cut out all classroom interaction and to make the teacher superfluous – although the rhetoric of some of its proponents and the caricatures of some of its adversaries at times might have given this impression.

In a further elaboration of the didactical structure – including the one about the waste issue – towards a decision-making strand in the curriculum these issues of the teacher's teaching style and the students' independent working/learning have to be addressed and reasonably solved in one way or another. From a research point of view it might be interesting to see whether or not these changes in emphasis would alleviate the teacher's task of preparation and implementation, and facilitate the students' learning.

The logical first step in the process of follow-up developmental research would thus be a revision of the unit about decision making on the waste issue, not only taking into account the ideas about the necessary modifications mentioned in chapter 6, but also addressing the above-mentioned issues of the teacher's teaching style and the students' independent working/learning. This could be followed by a larger scale testing, involving a variety of teachers (inexperienced in teaching the unit) and

students (of different ability levels) and adopting a more quantitative/comparative research design to further establish the validity of the didactical structure and to assess its learning effects.

In preparing the teachers for this larger scale testing the scenario and the reflected teaching practice from the first and second small-scale trials will have to be used productively in one way or another. It may be worthwhile to develop and test, again in a process of developmental research, a short but adequate in-service teacher-education course for learning to use the unit in classroom practice. In this course sufficient attention has to be paid to extending the teacher's didactical repertoire, if necessary from the point of view of the teacher's customary teaching style, in the direction of properly interpreting what the students are putting forward, conducting whole-class discussions and making the global and local teaching/ learning process explicit.

Teaching complex skills

A second direction for further developmental research could concern the teaching of *complex skills* other than decision making. In the generalised didactical structure of figure 7.2, the use of words such as 'decision making' or 'presenting an argued point of view' has been avoided. Instead, the term 'skill' is used, indicating, as already mentioned, that we think our experiences from this study may, at least hypothetically, be extrapolated to the teaching of other intellectual skills as well. This may be timely, because nowadays much debate is going on about the importance of learning 'general' skills in view of facilitating the students' transition from secondary to tertiary education (Boersma & Friebel, 1993). Drawing the most attention in science teaching is learning to design, to do research, to obtain and process information, to solve problems – and even learning to learn. What all these complex intellectual skills have in common is their dependence on the importance of meta-cognition, the ability to regulate and control one's own cognitive processes and attitudes. Much work has been done on describing and analysing the mentioned skills and on differentiating them into subordinate skills. A question of particular concern, however, is to what extent such skills can be considered as 'general' and content-independent (e.g., Perkins & Salomon, 1989). The didactical problem of how such skills can or should be taught is directly related to this question. It is in this didactical field that we think the present study makes a contribution, as will now be somewhat further explored exemplarily for the case of *problem solving*.

Problem solving – Attempts in the past to teach problem solving directly as a general skill, independent from the teaching of subject matter, have failed (Boekaerts & Simons, 1993). So, there seems to be consensus about the fact that the teaching of the skill should in one way or another be related to the teaching of content (Gabel & Bunce, 1994; Maloney, 1994). A step in this direction is to integrate the teaching of subject matter with the teaching of problem solving. In this respect, quite often the importance of a general 'heuristic for solving problems systematically' (a set of steps to be taken, or a set of heuristic rules to be followed) has been advocated (e.g.,

Mettes & Pilot, 1980). The heuristic rules to be followed in such a systematic problem-solving approach still conjure up the image of problem solving as a general skill, independent of the domain-specific knowledge to be used in such a procedure. A skill, therefore, that – once learned – is supposed to be relatively easy to use in a broad range of knowledge domains. There are, however, serious doubts about this domain-independency and this transferability of 'the' skill of problem solving (Hennessy *et al.*, 1993), as "the situated cognition literature shows that the thinking of 'experts' and lay people alike is intricately interwoven with the specific problem-solving context and sensibly adjusted to meet the situation's demands" (Hennessy, 1993). Others, therefore, have argued that such a general heuristic should at least be complemented by more domain-specific heuristics (Lijnse, 1994). It has also been argued that 'the' systematic problem-solving approach should not be seen as a general set of heuristic rules, as a number of its constituting general instructions only 'work' in close connection with domain-specific knowledge and skills (Kramers-Pals, 1994). Taconis & Ferguson-Hessler (1994) describe this in more detail in what they call the knowledge base of students, of which both content-specific knowledge and more general strategic knowledge are part. To improve the quality of this knowledge base in teaching, in particular with respect to the integration of conceptual and strategic knowledge, Taconis (1995) advocates explicit attention for different ways in which actual conceptual problems are being solved. We think, however, that in all these attempts a coherent rationale and didactical explicitation of teaching content and skills together is still lacking.

The generalised didactical structure as outlined in section 7.4 seems to be an adequate starting-point for arriving at precisely that what is now still lacking. After a global orientation on the topic to be taught, a problematisation should follow which asks, firstly, for an acquisition of relevant domain-specific knowledge, followed by an application of this knowledge in solving problems that, in a problem-posing approach, follow naturally from the way in which the topic has been introduced. By a reflection on the intuitive ways in which these problems have been solved so far, relevant domain-specific heuristics should be made explicit (in analogy with the content and presentation standards for an argued point of view). In teaching subsequent (related) topics, new sets of domain-specific heuristics may be developed, that might at some point be reflected upon and abstracted to represent some sort of general procedure such as the heuristic rules of a 'systematic problem solving approach' (in analogy with the heuristic for decision making). In that case the teaching/learning process has evolved over time from the concrete to the abstract, with maybe a bigger chance that students understand both such a general procedure and the way in which it could be used to tackle problems in new knowledge domains.

According to this outline, the teaching of problem solving would not be something that comes in as a strange extra, but would evolve quite naturally within the overall didactical framework, and thus be in coherence with the rest of the teaching/learning process. A similar hypothetical outline could be given for the other skills mentioned above. Whether this would really result in the expected improved

learning results, asks, of course, for more developmental research including high-quality curriculum development.

Curriculum development

The above-outlined directions for further developmental research both include (high-quality) curriculum development. In the study at hand, the didactical structure and its elaboration in terms of a scenario and student materials have been designed and tested in two full cycles of developmental research. From chapters 5 and 6 it must have become clear that designing the general and more specific teaching/learning process is not a straightforward and linear task. What is it that makes this task so *difficult* and *time-consuming*?

In order to achieve the intended teaching/learning process, in this case concerning the topic of decision making about the waste issue, something is needed that differs substantially from the usual 'top-down' writing and teaching of a – in the eyes of the one who writes and teaches – logical, content-dominated story with associated suitable exercises for the students. In a 'bottom-up' problem-posing teaching/learning process a student is asked to actively develop his or her existing knowledge and skills in a specific direction, to 'construct' the intended 'story' in interaction with fellow students, the teacher and the student materials. From the point of view of curriculum development this means that the story to be 'written' still has to be made explicit, though not in the student materials but in the scenario. The student materials, furthermore, should be such that they allow the story to be written by the students in a series of consecutive logical and coherent tasks. This also necessitates a shift in thinking about the student. Instead of wondering about the question whether or not the written story will be clear enough to the students, one has to think about their motives for learning, about how to productively use their pre-knowledge and skill, about what to expect concerning their reactions to each of the tasks put to them – about how to guide their 'construction' of the story in the intended direction. This required paradigm shift is not an easy one for someone like me, with ample experience in the usual 'top-down' curriculum development and classroom teaching – however student-centred this writing and teaching may have been.

Apart from the required paradigm shift – which might perhaps be considered as a personal problem of having to overcome my life-long habit – also the process of curriculum development could be considered as more complex. What appears to be necessary, first of all, is to frequently move 'vertically' between the general didactical structure and the detailed scenario and student materials in order to ensure that the intention of each of the identified phases of the didactical structure is being sufficiently expressed by its constituting tasks under construction. That is, the general and the specific teaching/learning process have to be developed in interaction. What is further needed, is to frequently move 'horizontally' between the specific tasks under construction in order to ensure their coherence in terms of purpose, character and sequence. This means a continuous reflection on why a specific task should be included at a specific point in the teaching/learning process:

how does it follow from the preceding task and how does it prepare for the next one? That is, the specific tasks making up the teaching/learning process have to be developed in interaction. The combination of both the 'vertical' and the 'horizontal' interactions makes the process of curriculum development rather complicated, as is illustrated by the structural design errors described in chapter 5 and the still necessary fine-tuning and revision of the scenario and student materials indicated in chapter 6.

The required changes in thinking about the character of the teaching/learning process and the process of actually designing it imply that one cannot any longer rely on an implicit, intuitive assessment of 'what works and what doesn't', stemming from practical curriculum development and classroom experiences. These experiences are still useful, but now for explicitly formulating expectations about what will be put forward by the students as a result of each task, as a necessary input into the design process. The seemingly logical and coherent package of didactical structure, scenario and student materials described in chapters 3 and 4 is therefore the result of a rather strenuous and time-consuming process of interactive development of each of these components, at first complicated by a still misty answer to the question of what to expect in classroom practice, but gradually acquiring the required empirical basis.

7.6 Conclusion

The specific research questions arrived at in chapter 2 of this study have been answered to quite some extent, certainly as far as the adequate body of issue knowledge, adequate decision-making procedure and proper interpretation of the students' pre-knowledge and decision-making skill are concerned. The question of what constitutes a good enough bottom-up teaching/learning process has been answered to a somewhat lesser extent, as part of the empirical support from classroom practice is still lacking. However, on the basis of the available empirical data it can be hypothesised with quite some confidence that an experience-based improved scenario and teaching practice will make the teaching/learning process progress as intended.

The question of what constitutes an adequate teacher preparation has also not been fully answered. Although the scenario has proven to be a valuable instrument for the teacher's pre-trial preparation and classroom practice, additional reflected teaching practice seems to be necessary for making the teaching/learning process progress as intended. In the context of the recent changes in 'educational policy', however, the question has been raised whether an elaboration of the didactical structure that draws heavily on the teacher's capability of guiding whole-class discussions can be considered desirable. A change of emphasis towards students' independent working/learning would also have an impact on what is thought to constitute an adequate teacher preparation.

By using the results of the classroom trial as described in chapter 6, the elaboration of the didactical structure for decision making about packages in terms

of the scenario and student materials can be made ‘good enough’. It might be more sensible, however, to see if those results can be used productively for a major revision in terms of making the unit’s working methods comply with the above-mentioned changes in educational policy and for designing an accessory in-service teacher education course. A more far-reaching perspective is offered by the generalised didactical structure emerging from this study, as this structure seems to have some potential for acting as a starting-point for developing a decision-making strand in the science curriculum as well as for extending it to other intellectual skills such as problem solving.

This starting-point has been generated by going from the concrete to the abstract: from the didactical structure for decision making about the waste issue to the problem-posing and level-structured didactical structure presented in this chapter. Regardless of which of the above-outlined directions for further developmental research will be chosen, each direction implies going back from the abstract to the concrete. In this process the construction of an adequate ‘theoretical framework’ such as the one in chapter 3 and the subsequent elaboration into a scenario and student materials as illustrated in chapters 4 and 5 seem to be necessary requirements for designing and testing of didactical structures. Intuitive development of teaching/learning materials and a superficial testing of whether or not they seem ‘to work’ as described in chapter 2 is clearly not good enough to arrive at good classroom practice.

References

Abraham, M.R. (1998), The learning cycle approach as a strategy for instruction in science. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 513-524). Dordrecht: Kluwer.

Aikenhead, G. (1991), *Logical reasoning in science and technology*. Toronto: John Wiley & Sons.

Aikenhead, G. (1994), What is STS science teaching? In J. Solomon & G. Aikenhead (Eds.), *STS Education - International perspectives on reform* (pp. 47-59). New York, NY: Teachers College Press.

Alblas, A.H. (1999), *Onderwijzen voor een natuurbetrokken bestaan – Didactische uitgangspunten voor natuur- en milieu-educatie*. Wageningen: Wageningen Universiteit.

Alblas, A.H., J.J.S. Broertjes, F.J.J.M. Janssen & A.J. Waarlo (1993), *Begrip en betrokkenheid. Bouwstenen voor leerbare thema's in natuur- en milieu-educatie*. Wageningen/Utrecht: Vakgroep Agrarische Onderwijskunde Landbouwuniversiteit Wageningen, Vakgroep Didactiek van de Biologie Universiteit Utrecht.

American Chemical Society (1988), *ChemCom: Chemistry in the community*. Dubuque, IA: Kendall/Hunt.

Anderson, R.D. (1995a), *Final technical research report: Study of curriculum reform*. Boulder, CO: University of Colorado.

Anderson, R.D. (1995b), Curriculum reform: Dilemmas and promise. *Phi Delta Kappa, 77* (1), 33-36.

Baron, J. & R.V. Brown (1991a), Introduction. In J. Baron & R.V. Brown (Eds.), *Teaching decision making to adolescents* (pp. 7-18). Hillsdale, NJ: Lawrence Erlbaum Associates.

Baron, J. & R.V. Brown (1991b), Toward improved instruction in decision making to adolescents: a conceptual framework and pilot program. In J. Baron & R.V. Brown (Eds.), *Teaching decision making to adolescents* (pp. 95-122). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bayes, T. (1763), An essay toward solving a problem in the doctrine of chances. *Philosophical Transactions of the Royal Society of London*. Reprinted in *Biometrika, 45*, 293-315 (1958) and in E.S. Pearson & M.G. Kendall (Eds.) (1970), *Studies in the history of statistics and probability*. London: Charles Griffin.

Beyth-Marom, R., B. Fischhoff, M. Jacobs Quadrell & L. Furby (1991), Teaching decision making to adolescents: a critical review. In J. Baron & R.V. Brown (Eds.), *Teaching decision making to adolescents* (pp. 19-59). Hillsdale, NJ: Lawrence Erlbaum Associates.

Black, P. & J.M. Atkin (Eds.) (1996), *Changing the subject: Innovations in science, mathematics and technology education*. London: Routledge.

Boekaerts, M. & P.R.J. Simons (1993), *Leren en instructie – Psychologie van de leerling en het leerproces*. Assen: Dekker & Van de Vegt.

Boersma, K.Th. (1986), De *E* van NM*E* – Onderwijskundige, vakdidactische en pedagogische uitgangspunten van natuur- en milieu-educatie. *Bulletin voor het Onderwijs in de Biologie, 17* (103), 200-208.

Boersma, K.Th. (1994), Probleemoplossen in de β-vakken. *Tijdschrift voor Didactiek der β-wetenschappen (TDβ), 12* (3), 165-171.

Boersma, K.Th. & A. Friebel (1993), *Algemene vaardigheden in de β-profielen – Een discussienotitie*. Enschede: Instituut voor Leerplanontwikkeling (SLO).

Boud, D. & G.I. Feletti (Eds.) (1997), *The challenge of problem-based learning* (2nd ed.). London: Kogan Page.

Bridges, D. (1979), *Education, democracy and discussion*. Windsor: NFER.

Brim Jr., O.G., D.C. Glass, D.E. Lavin & N. Goodman (1962), *Personality and decision processes*. Stanford, CA: Stanford University Press.

Bullough, R.V., Jr. & A.D. Gitlin (1994), Challenging teacher education as training: four propositions. *Journal of Education for Teaching, 20* (1), 67-81.

Bybee, R.W. & T. Mau (1986), Science and technology related global problems: An international survey of science educators. *Journal of Research in Science Teaching, 23* (7), 599-618.

Calderhead, J. (1989), Reflective teaching and teacher education. *Teaching & Teacher Education, 5* (1), 43-51.

Carroll, J.S. & E.J. Johnson (1990), *Decision research - A field guide*. London: Sage Publications.

Cassidy, E.W. & D.G. Kurfman (1977), Decision making as purpose and process. In D.G. Kurfman (Ed.), *Developing decision making skills* (pp. 1-26). Arlington, VA: National Council for the Social Studies.

CHE (1990), *Advies kerndoelen voor de basisvorming in basisonderwijs en voortgezet onderwijs*. Lelystad: Commissie Herziening Eindtermen (CHE).

Cramer, J. & J. Quakernaat (1993), Integraal ketenbeheer en technologie-ontwikkeling. *Milieu – Tijdschrift voor Milieukunde, 8* (5), 202-207.

de Jager, H. & F.A. van der Loo (1990), Decision-making in environmental education: notes from research in the Dutch NME-VO project. *Journal of Environmental Education, 22* (1), 33-43.

de Jonge, R., F.H. Peters, R. Langras & H.R. Leene (1993), *Nu voor straks – Natuur- en scheikunde voor de basisvorming 1 MHV*. Zutphen: Thieme.

Driver, R. (1989), Changing conceptions. In P. Adey, J. Bliss, J.Head & M. Shayer (Eds.), *Adolescent development and school science* (pp. 79-103). London: Falmer Press.

Driver, R., H. Asoko, J. Leach, E. Mortimer & P. Scott (1994), Constructing scientific knowledge in the classroom. *Educational Researcher, 23* (7), 5-12.

Driver, R. & V. Oldham (1986), A constructivist approach to curriculum development in science. *Studies in Science Education, 13*, 105-122.

Duit, R., F. Goldberg & H. Niedderer (Eds.) (1992), *Research in physics learning: theoretical issues and empirical studies*. Kiel: Institut für die Pedagogik der Naturwissenschaften (IPN).

Duit, R. & D.F. Treagust (1998), Learning in science – From behaviourism towards social constructivism and beyond. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 3-25). Dordrecht: Kluwer.

Eberg, J.W., H.M.C. Eijkelhof, J. Kortland & K.M. Stokking (1991), *Naar een didactiek voor natuur- en milieu-educatie in het onderwijs*. Utrecht: Interdisciplinair Sociaal-wetenschappelijk Onderzoeksinstituut Rijksuniversiteit Utrecht (ISOR), Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ).

Eijkelhof, H.M.C. (1990), *Radiation and risk in physics education*. Utrecht: Cdβ Press.

Eijkelhof, H.M.C. (1999), Social issues and physics at 16+ in Europe. In R. Coughlan (Ed.), *Attainment in physics – Proceedings of the colloquium on attainment in physics at 16+* (pp. 33-50). Dublin: Department of Education and Science.

Eijkelhof, H.M.C. & J. Kortland (1988), Broadening the aims of physics education. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 282-305). London: Falmer Press.

Eijkelhof, H.M.C., J. Kortland & F.A. van der Loo (1984), Nuclear weapons – a suitable topic for the classroom? *Physics Education, 19*, 11-15.

Eijkelhof, H.M.C. & P.L. Lijnse (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.

Fensham, P.J. (1988), Familiar but different: some dilemmas and new directions in science education. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 1-26). London: Falmer Press.

Fleming, R. (1986a), Adolescent reasoning in socio-scientific issues, part I: social cognition. *Journal of Research in Science Teaching, 23* (8), 677-687.

Fleming, R. (1986b), Adolescent reasoning in socio-scientific issues, part II: non-social cognition. *Journal of Research in Science Teaching, 23* (8), 689-698.

Fleming, R. (1987), How students reason in socioscientific issues. In I. Lowe (Ed.), *Teaching the interactions of science, technology and society* (pp. 313-318). Melbourne: Longman Cheshire.

Freudenthal, H. (1991), *Revisiting mathematics education*. Dordrecht: Kluwer.

Gabel, D.L. & D.M. Bunce (1994), Research on problem solving: chemistry. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 301-326). New York: Macmillan.

Gouran, D.S. & R.Y. Hirokawa (1996), Functional theory and communication in decision-making and problem-solving groups. In R.Y. Hirokawa & M.S. Poole (Eds.), *Communication and group decision making* (pp. 55-80). Thousand Oakes, CA: Sage Publications.

Gravemeijer, K.P.E. (1994), *Developing realistic mathematics education*. Utrecht: Cdβ Press.

Hameyer, U., J. van den Akker, R.D. Anderson & M. Ekholm (1995), *Portraits of productive schools – An international study of institutionalizing activity-based practices in elementary science*. Albany, NY: State University of New York Press.

Hennessy, S. (1993), Situated cognition and cognitive apprenticeship: implications for classroom learning. *Studies in Science Education, 22*, 1-41.

Hennessy, S., R. McCormick & P. Murphy (1993), The myth of general problem-solving capability: design and technology as an example. *The Curriculum Journal, 4* (1), 73-89.

Hewson, P.W., M.E. Beeth & N.R. Thorley (1998), Teaching for conceptual change. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 199-218). Dordrecht: Kluwer.

Hines, J.M., H.R. Hungerford & A.N. Tomera (1987), Analysis and synthesis of research on responsible environmental behaviour: a meta-analysis. *Journal of Environmental Education, 18* (2), 1-8.

Hofstein, A., G. Aikenhead & K. Riquarts (1988), Discussions over STS at the fourth IOSTE Symposium. *International Journal of Science Education, 10* (4), 357-366.

Hungerford, H.R., R.B. Peyton & R.J. Wilke (1980), Goals for curriculum development in environmental education. *Journal of Environmental Education, 11* (3), 42-47.

Hungerford, H.R. & T.L. Volk (1990), Changing learner behaviour through environmental education. *Journal of Environmental Education, 21* (3), 8-21.

Hunt, J.A. (1988), SATIS approaches to STS. *International Journal of Science Education, 10* (4), 409-420.

Janis, I.L. & L. Mann (1977), *Decision making. A psychological analysis of conflict, choice and commitment*. New York: Free Press.

Janssen, F.J.J.M. (1999), *Ontwerpend leren in het biologieonderwijs*. Utrecht: Cdβ Press.

Jarboe, S. (1996), Procedures for enhancing group decision making. In R.Y. Hirokawa & M.S. Poole (Eds.), *Communication and group decision making* (pp. 55-80). Thousand Oakes, CA: Sage Publications.

Jeffrey, R.C. (1983), *The logic of decision* (2nd ed.). Chicago: University of Chicago Press.

Joyce, B. & B. Showers (1988), *Student achievement through staff development*. New York: Longman.

Klaassen, C.W.J.M. (1995), *A problem-posing approach to teaching the topic of radioactivity*. Utrecht: Cdβ Press.

Klaassen, C.W.J.M. & P.L. Lijnse (1996), Interpreting students' and teachers' discourse in science classes: an underestimated problem? *Journal of Research in Science Teaching, 33* (2), 115-134.

Klayman, J. (1985), Children's decision strategies and their adaptation to task characteristics. *Organizational Behavior and Human Decision Processes, 35*, 179-201.

Korthagen, F.A.J. (1999), Linking reflection and technical competence: the logbook as an instrument in teacher education. *European Journal of Teacher Education, 22* (2/3), 191-207.

Korthagen, F.A.J. & J.P.A.M. Kessels (1999), Linking theory and practice: changing the pedagogy of teacher education. *Educational Researcher, 28* (4), 4-17.

Kortland, J. (1987), Curriculum emphases in the PLON physics curriculum. In I. Lowe (Ed.), *Teaching the interactions of science, technology and society* (pp. 231-240). Melbourne: Longman Cheshire.

Kortland, J. (1989), Environmental education within the science subjects in secondary education: why, what and what for? *La Fisica nella Scuola, 22* (4), 98-106.

Kortland, J. (1991), *Afval – leerlinginterviews*. Utrecht/Enschede: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ), Instituut voor Leerplanontwikkeling (SLO).

Kortland, J. (1992a), Environmental education: sustainable development and decision making. In R.E. Yager (Ed.), *The status of STS reform efforts around the world* (pp. 32-39). Knapp Hill: International Council of Associations for Science Education (ICASE).

Kortland, J. (1992b), *Afval – verslag ontwikkelingsonderzoek*. Utrecht/Enschede: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ), Instituut voor Leerplanontwikkeling (SLO).

Kortland, J. (1992c), *Natuur- en milieu-educatie in het vak natuur- en scheikunde in de basisvorming: blauwdrukken*. Utrecht/Enschede: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ), Instituut voor Leerplanontwikkeling (SLO).

Kortland, J. (Ed.) (1994), *Interactief – Natuurkunde/scheikunde voor de basisvorming 1MHV*. Zutphen: Thieme.

Kortland, J. (1996a), An STS case study about students' decision making on the waste issue. *Science Education, 80* (6), 673-689.

Kortland, J. (1996b), Decision making on science-related social issues: the case of garbage in physical science – A problem-posing approach. In G. Welford, J. Osborne & P. Scott (Eds.), *Research in science education in Europe – Current issues and themes* (pp. 115-125). London: Falmer Press.

Kortland, J. (1997), Garbage: dumping, burning or reusing/recycling: students' perception of the waste issue. *International Journal of Science Education, 19* (1), 65-77.

Kortland, J. & M. Pieters (1990), *Vakdeelleerplan natuur- en milieu-educatie in de basisvorming: natuur- en scheikunde*. Utrecht/Enschede: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ), Instituut voor Leerplanontwikkeling (SLO).

Kortland, J. & I. Veldman (1992), *Besluitvorming van leerlingen - Ideeën voor lesmateriaalontwikkeling en onderzoek*. Enschede: Instituut voor Leerplanontwikkeling (SLO).

Kramers-Pals, H. (1994), Zijn probleemoplossingsvaardigheden domeingebonden? *Tijdschrift voor Didactiek der β-wetenschappen (TDβ), 12* (3), 195-209.

Layton, D. (1994), STS in the school curriculum: a movement overtaken by history? In J. Solomon & G. Aikenhead (Eds.), *STS Education - International perspectives on reform* (pp. 32-44). New York: Teachers College Press.

Lewis, J. (Proj. Dir.) (1981), *Science in society*. London: Heinemann Educational.

Lijnse, P.L. (1994), Probleemoplossen en algemene vaardigheden: een poging tot discussie. *Tijdschrift voor Didactiek der β-wetenschappen (TDβ), 12* (3), 246-260.

Lijnse, P.L. (1995), 'Developmental research' as a way to an empirically based 'didactical structure' of science. *Science Education, 79* (2), 189-199.

Lijnse, P.L. (2000), Didactics of science: the forgotten dimension in science education research? In R. Millar, J. Leach & J. Osborne (Eds.), *Improving science education – The contribution of research* (pp. 308-326). Buckingham: Open University Press.

Lijnse, P.L., J. Kortland, H.M.C. Eijkelhof, D. van Genderen & H.P. Hooymayers (1990), A thematic physics curriculum: a balance between contradictory curriculum forces. *Science Education, 74*, 95-103.

Lindblom, C.E. (1959), The science of 'muddling through'. *Public Administration Review, 19*, 79-88.

Lucas, A.M. (1980), Science and environmental education: pious hopes, self-praise and disciplinary chauvinism. *Studies in Science Education, 7*, 1-26.

Maloney, D.P. (1994), Research on problem solving: physics. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 327-354). New York: Macmillan.

Matthews, M.R. (1994), *Science teaching: the role of history and philosophy of science*. New York: Routledge.

Meijer, W.A.J. (1992), Milieu-onderwijs, geen moraalonderwijs. In K.Th. Boersma (Ed.), *Milieuproblemen in het basisonderwijs* (pp. 33-46). Enschede: Instituut voor Leerplanontwikkeling (SLO).

Mettes, C.T.C.W. & A. Pilot (1980), *Over het leren oplossen van natuurwetenschappelijke problemen*. Enschede: Universiteit Twente.

Millar, R. & J. Osborne (1999), *Beyond 2000: science education for the future*. London: Kings' College.

Moust, J.H.C., P.A.J. Bouhuijs & H.G. Schmidt (1992), *Probleemgestuurd leren*. Groningen: Wolters-Noordhoff.

Nussbaum, J. & S. Novick (1982), Alternative frameworks, conceptual conflict and accommodation: toward a principled teaching strategy. *Instructional Science, 11*, 183-200.

OCW (1998), *Kerndoelen basisvorming 1998-2003*. Den Haag: SDU.

Ogborn, J. (1997), Constructivist metaphors of learning science. *Science & Education, 6*, 121-133.

Ormond, C., M.A. Luszcz, L. Mann & G. Beswick (1991), A metacognitive analysis of decision making in adolescence. *Journal of Adolescence, 14*, 275-291.

Perkins, D.N. & G. Salomon (1989), Are cognitive skills context-bound? *Educational Researcher, 16*, 16-25.

Pieters, M. (Ed.) (1990), *Teaching for sustainable development*. Enschede: Instituut voor Leerplanontwikkeling (SLO).

Pieters, M., M. Broné & G. Kölker (1998), *Inhoud geven aan natuur- en milieu-educatie – Verkenning van NME in het vernieuwde voortgezet onderwijs*. Enschede: Instituut voor Leerplanontwikkeling (SLO).

Posner, G.J., K.A. Strike, P.W. Hewson & W.A. Gertzog (1982), Accommodation of a scientific conception; toward a theory of conceptual change. *Science Education, 66*, 211-227.

Ratcliffe, M. (1994), Decision making about science-related social issues. In K.Th. Boersma, J. Kortland & J. van Trommel (Eds.), *Science and technology education in a demanding society* (vol. 3, pp. 722-732). Enschede: Instituut voor Leerplanontwikkeling (SLO).

Ratcliffe, M. (1997), Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education, 19* (2), 167-182.

Ratcliffe, M. (1999), Exploring aspects of scientific literacy in the classroom – evidence based decision-making. In O. de Jong, J. Kortland, A.J. Waarlo & J. Buddingh' (Eds.), *Bridging the gap between theory and practice: what research says to the science teacher* (pp. 51-67). Utrecht: Centrum voor Didactiek van Wiskunde en Natuurwetenschappen (Cdβ), International Council of Associations for Science Education (ICASE).

RIVM (1989), *Afval 2000 – Een verkenning van de toekomstige afvalverwijderingsstructuur*. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu (RIVM).

RIVM & VROM (1989), *Verpakkingsafval*. Bilthoven/Den Haag: Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieu (VROM).

Roberts, D.A. (1982), Developing the concept of 'curriculum emphases' in science education. *Science Education, 66*, 243-260.

Schools Council Integrated Science Project (1973), *Patterns*. London: Longman.

Sia, A.P., H.R. Hungerford & A.N. Tomera (1986), Selected predictors of responsible environmental behaviour: an analysis. *Journal of Environmental Education, 17* (2), 31-40.

Simon, H.A. (1976), *Administrative behavior: a study of decision-making processes in administrative organization* (3rd ed.). New York: The Free Press.

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

Solomon, J. (1992), The classroom discussion of science-based social issues presented on television: knowledge, attitudes and values. *International Journal of Science Education, 14* (4), 431-444.

Solomon, J. (1994), Conflict between mainstream science and STS in science education. In J. Solomon & G. Aikenhead (Eds.), *STS Education - International perspectives on reform* (pp. 3-10). New York, NY: Teachers College Press.

Taconis, R. (1995), *Understanding based problem solving: towards a qualification-oriented teaching and learning in physics education*. Eindhoven: Universiteit Eindhoven.

Taconis, R. & M. Ferguson-Hessler (1994), Het belang van probleemoplossen voor het onderwijs in technische en exacte vakken. *Tijdschrift voor Didactiek der β-wetenschappen (TDβ), 12* (3), 172-194.

ten Voorde, H.H. (1977), *Verwoorden en verstaan*. Den Haag: SVO/SDU.

ten Voorde, H.H. (1980), Education based on a new concept of teaching in chemistry. In W.F. Archenhold, R.H. Driver, A. Orton & C. Wood-Robinson (Eds.), *Cognitive development – Research in science and mathematics* (pp. 310-320). Leeds: University of Leeds.

Thier, H.D. & T. Hill (1988), Chemical education in schools and the community: the CEPUP project. *International Journal of Science Education, 10* (4), 421-430.

Tversky, A. (1972), Elimination by aspects: a theory of choice. *Psychological Review, 79* (4), 281-299.

Udo de Haes, H.A. (1984), Milieukunde, begripsbepaling en afbakening. In J.J. Boersema, J.W. Copius Peereboom & W.T. de Groot (Eds.), *Basisboek milieukunde* (pp. 17-30). Amsterdam: Boom.

van Aalsvoort, J.G.M. (2000), *Chemistry in products – A cultural-historical approach to initial chemical education*. Utrecht: Universiteit Utrecht.

van Boxtel, C.A.M. (2000), *Collaborative concept learning – Collaborative learning tasks, student interaction and the learning of physics concepts*. Utrecht: Universiteit Utrecht.

van den Akker, J. (1998), The science curriculum: Between ideals and outcomes. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 421-447). Dordrecht: Kluwer.

van Hiele, P.M. (1986), *Structure and insight – A theory of mathematics education*. Orlando: Academic Press.

Verloop, N. (1992), Praktijkkennis van docenten: een blinde vlek van de onderwijskunde. *Pedagogische Studiën, 69*, 410-423.

Vollebregt, M.J. (1998), A problem posing approach to teaching an initial particle model. Utrecht: Cdβ Press.

VROM (1986), *Scheiden aan de bron en gescheiden inzameling van delen van huishoudelijk afval – Een vergelijking van systemen*. Den Haag: Ministerie van Volksgezondheid, Ruimtelijke Ordening en Milieu (VROM).

WEN (1988), *Advies examenprogramma natuurkunde VWO en HAVO*. Enschede: Werkgroep Eindexamenprogramma's Natuurkunde (WEN).

Wierstra, R.F.A. (1990), *Natuurkundeonderwijs tussen leefwereld en vakstructuur*. Utrecht: Cdβ Press.

Witte, E. (1972), Field research on complex decision making processes – The phase theorem. *International Studies of Management and Organization*, 157-182.

White, R.T. (1987), The future of research on cognitive structure and conceptual change. *Tijdschrift voor Didactiek der β-wetenschappen (TDβ), 5* (3), 161-172 (invited address for the special interest group Cognitive Structure and Conceptual Change, AERA 1987, Washington).

Wubbels, Th., F.A.J. Korthagen & M. Brekelmans (1997), Developing theory from practice in teacher education. *Teacher Education Quarterly, 24* (3), 4-17.

Yager, R.E. (Ed.) (1996), *Science/technology/society as reform in science education*. Albany, NY: State University of New York Press.

Zoller, U. (1987), Problem solving and decision making in science-technology-environmental-society (STES) education. In K. Riquarts (Ed.), *Science and technology and the quality of life – Proceedings of the 4th International Symposium on World Trends in Science and Technology Education* (vol. 2, pp. 562-569). Kiel: Institut für die Pedagogik der Naturwissenschaften (IPN).

Summary

This thesis describes a study undertaken at the *Centre for Science and Mathematics Education* at Utrecht University during the 1990s. The study deals with *the teaching and learning of decision making on the waste issue* as an example of a science/ technology-related social issue in the physical science curriculum at the junior secondary level. A first motive for undertaking this study can be found in the introduction of decision making in the attainment targets for this type of education in the early 1990s – a 'new' attainment target that was considered to be in need of operationalisation in extension of my personal involvement in the centre's two preceding curriculum development projects in the 1980s (the PLON project and the NME-VO project) in which decision making by students was intuitively developed but barely researched. A second motive concerned the centre's emerging programme of developmental research about 'didactical structures' reflecting a problem-posing approach to teaching specific science topics – a programme that could be 'enriched' with an example of such an approach for the interrelated teaching/learning of (waste issue) knowledge and (decision-making) skill.

The first chapter in this thesis shows how both motives are 'grounded' in curriculum development in the area of *science-technology-society education* and *environmental education* and in didactical research aimed at improving teaching/ learning processes under the umbrella of *educational constructivism*, culminating in the *general research question* for this study: what constitutes an adequate didactical structure through which students in junior secondary education learn to use their acquired knowledge about the waste issue in a satisfactory decision-making procedure? This question is explored to some extent in chapter 2 with a description of and a critical reflection on my earlier attempts at intuitively designing and testing such a didactical structure within the NME-VO project, resulting in a number of *specific research questions* about an adequate body of issue knowledge and an adequate decision-making procedure, about the students' existing pre-knowledge and decision-making skill, about the desired character of the teaching/learning process and about an adequate teacher preparation on its trial. The ideas about the answers to those questions are elaborated in chapter 3, resulting in a (still hypothetical) didactical structure for teaching the topic under consideration. This chapter also addresses the use of a *scenario* as an instrument for designing the sequence of student tasks, for preparing the teacher on the classroom trial and for evaluating this trial. The consecutive chapters 4, 5 and 6 then deal with the product, the process and the test, respectively. The product in chapter 4 is the 'final' version of the teaching/ learning unit as an operationalisation of the topic-specific didactical structure after two complete cycles of developmental research. The process in chapter 5 concerns the 'history' of this product, and focuses on the classroom trial of the unit's first

version. It not only reveals the validity of the assumptions about the students' issue knowledge and decision-making skill, but also the structural errors in the design of the teaching/learning process and the inadequate preparation of the trial teacher. This chapter also outlines the ensuing modifications of the unit's first version and the teacher's preparation on the classroom trial of the unit's second version. The results of testing the unit's second version are presented in chapter 6. These trial results are used to tentatively answer the question whether or not the teaching/ learning unit – and therefore its underlying didactical structure – now is 'good enough' for practical purposes. That is: effective classroom teaching.

The thesis is concluded in chapter 7 with a reflection on the results of this study in the light of the two broad motives for undertaking it and a summary of the answers to the specific research questions. This is followed by an attempt to describe the resulting topic-specific didactical structure in more general terms and a brief exploration of its potential for further developmental research in the area of teaching complex intellectual skills.

A problem-posing approach – The title of this thesis reflects an emphasis on *a problem-posing approach* to teaching. In the concluding chapter of this thesis such a problem-posing approach is described in general terms as a sequence of six consecutive teaching phases which each have a distinct didactical function. In retrospect, these phases also seem to apply to some extent to the contents of this thesis. The following, more extensive summary will therefore be 'organised' under the headings of these teaching phases – of which the labels are still tentatively formulated …

Motivation phase

The first phase of a problem-posing teaching/learning process has the didactical function of *orienting and evoking a global interest in and motive for studying the topic at hand*.

In the thesis at hand this didactical function is represented by chapter 1. This chapter first outlines three movements in Dutch secondary education over the past decades that have provided a motive for undertaking this study: the emergence of *science, technology and society education* and *environmental education*, a growing perceived importance of and emphasis on students' *skills*, and an attempt at applying *constructivist ideas* about teaching and learning to classroom practice. Or, in other words: a shift of emphasis with respect to *contents*, *skills* and *teaching/learning process* – a shift of emphasis towards science contents in an everyday life context, towards skills to use these contents productively, and towards a teaching/learning process to reach these aims effectively.

The above-mentioned first two movements have led to the introduction of an attainment target about *decision making* on science/technology-related social issues (including *environmental issues*) in the physical science programme at the junior secondary level. An overview of (scarce) didactical research on students' decision making in science education points at a not unproblematic tuning of conceptual science knowledge to everyday life decision-making situations in which it has to be

used productively. Furthermore, a clear operationalisation of the decision-making attainment target seems to be lacking. Both issues provided a first broad motive for undertaking the study at hand.

The above-mentioned third movement reflects the adoption of *educational constructivism* in which learning is viewed as a process in which the learner is actively involved in the integration of new experiences and information into what he or she already knows. Constructivist teaching/learning strategies such as the status-changing model of conceptual change and conflict strategies, however, do seem to be problematic as far as the status and interpretation of the students' existing knowledge as a starter for their learning process is concerned. This has led to the idea of a *problem-posing approach* to the teaching/learning of a topic, in which the teaching/learning process reflects a careful balance between 'guidance from above' (by the teacher and the teaching materials) and 'freedom from below' (for the students) the core of which consists of developing the students' *content-related motives* for extending their knowledge in the intended direction. The issue of how to operationalise this in terms of a didactical structure for the interrelated teaching/learning of knowledge and skill provided a second broad motive for undertaking the study at hand.

Designing such a didactical structure is a topic-specific activity. The topic chosen is *decision making* about the *waste issue*, one of the environmental issues featuring in the attainment targets for physical science at the junior secondary level. Designing a topic-specific didactical structure asks for an empirical process of closely interconnected research and development: *developmental research* – a cyclical process of reflection on contents and teaching/learning process, small-scale curriculum development and teacher preparation, and classroom research of the interaction of teaching and learning processes. This eventually leads to an empirically based description and justification of the teaching/learning process for the topic under consideration: a *didactical structure*.

With this overview of the issues to be addressed and making explicit the broad motives for addressing these, the first chapter hopefully has fulfilled its didactical function of orienting and evoking a global interest in and a motive for studying the topic at hand. That is, the remaining chapters of this thesis.

Question phase

The second phase of a problem-posing teaching/learning process has the didactical function of *narrowing down this global motive into a content-specific need for more knowledge*.

In the thesis at hand, the second chapter is trying to do just that by critically reflecting on earlier attempts at *intuitively* designing and testing a teaching/learning unit about the chosen topic of decision making on the waste issue within the NME-VO project in the late 1980s and early 1990s. The classroom trials of this garbage unit were rather unsatisfactory with respect to learning outcomes. Throughout the description of the design and classroom tests of the garbage unit's first version in

this chapter, a number of questions emerge about the character of the teaching/ learning process as an example of a strategy of 'top-down' transmission, about eliciting but not productively using the students' pre-knowledge, about the proper interpretation of the students' existing pre-knowledge and decision-making skill, about the adequacy of the transmitted science knowledge for the decision-making exercises, etc. These questions, however, have been formulated in retrospect and were therefore not addressed in the revision of the garbage unit for a second round of classroom testing. This revision was guided by quite another question: how to explicitly address the students' supposed *misconceptions* in the areas of issue knowledge and decision making. More or less in line with ideas about constructivist teaching and learning at that time, the answer to this question was sought in the direction of using some kind of *conflict strategy* in a number of additional teaching/ learning activities. The classroom trials again showed disappointing learning effects, now attributed to the teacher's difficulty of giving up the familiar role of instructor and a lack of sufficient procedural specification helping the trial teacher in preparing for and carrying out the actual teaching. However, in retrospect, a more valid explanation might have been that the students' pre-knowledge and decision-making skill was being interpreted in a wrong way: instead of assuming this pre-knowledge to include misconceptions and this decision-making skill to be limited, one should look for a more 'charitable' interpretation that makes students' pre-knowledge and skill make sense and that can be used productively in a teaching/learning process aimed at extending these in a direction specified by the unit's educational aims.

The critical reflection on the earlier topic-specific research and development work in this second chapter has thus given rise to a number of specific research questions about what constitutes an adequate body of issue knowledge as conceptual input into the students' decision making, an adequate and explicit decision-making procedure, a proper interpretation of their pre-knowledge about the waste issue and their decision-making skill, a good enough 'bottom-up' teaching/learning process, and an adequate teacher preparation for implementing it in classroom practice. Questions that will have to be investigated through developmental research …

Investigation phase

The third phase of a problem-posing teaching/learning process has the didactical function of *extending the students' existing knowledge, in view of the global motive and the more specifically formulated knowledge need*.

In the case of the developmental research described in this thesis such an 'extension of existing knowledge' means trying to find answers to the questions emerging from the preceding phase. Chapter 3 therefore represents a reflection on the desired contents and teaching/learning process, leading up to a still hypothetical *didactical structure* for the teaching/learning of the topic under consideration. Chapter 4 then outlines the elaboration of this didactical structure into a *teaching/learning unit*: a scenario and associated student materials in terms of a workbook and reference materials. The scenario gives a description and justification of what is expected to happen in the interaction between teacher and students in classroom practice when

working on the tasks making up the student materials. The *scenario* thus serves as a tool to design concrete tasks for the students, to prepare the teacher on the classroom trial, to focus the classroom observations during the trial, and to guide a post-trial reflection on the quality of the designed and actual teaching/learning process.

In order to avoid repetition, both chapters – about the didactical structure and about its elaboration into a teaching/learning unit – will be summarised in combination, focusing on the key features of students' existing and developing *knowledge and skill*, the problem-posing character of the *teaching/learning process* and the teacher's required *teaching style*.

Knowledge and skill – Chapter 3 first summarises the literature-based ideas about a structure of environmental issues in general and the waste issue in particular. For reasons of limited teaching time and the characteristics of the target population of grade 8, middle ability students, the waste issue is limited to discarded packages in household garbage while the energy aspects of packaging and waste processing are not taken into account. The structure of the thus limited waste issue reflects the variety of life cycles of packages, connected to depletion of raw materials and pollution through dumping and burning of waste as environmental problems. With respect to decision making, a search for an *adequate decision-making procedure* results in a stepwise sequence of identifying the problem, developing criteria, generating alternatives, evaluating the generated alternatives on the developed criteria, and finally choosing and implementing the best solution. In connection to the waste issue, the relevant criteria can be drawn from the waste issue's structure: the extent to which packaging alternatives contribute to *depletion* of resources and to *pollution* of soil, water and air – as these are the environmental problems that trigger the need for decision making from an environmental point of view. This allows the identification of an *adequate body of issue knowledge*: knowledge about the general structure of the waste issue is necessary for identifying the relevant environmental criteria for evaluating packaging alternatives, and knowledge about the criteria-related properties of packages and packaging materials is necessary in order to actually evaluate packaging alternatives on the identified criteria. What is further needed in order to design a didactical structure, is an idea about how the students' pre-knowledge and decision-making skill relate to what is thought to be adequate. Contrary to the 'findings' in the preceding phase of 'exploratory research and development' concerning the NME-VO project's garbage unit, now the position is taken that the students as a result of their everyday life experiences and preceding formal education already know about the general structure of the waste issue – apart from some specific issue-related terminology. This means that students are expected to have a clear enough idea about the production of packaging materials including the possible depletion of non-renewable resources, about waste processing through dumping and burning including the possible pollution of soil, water and air, and about prevention and reusing/recycling as possibilities to counter depletion and pollution. Furthermore, the position is taken that the students in their own everyday life decision making are familiar with either implicitly or explicitly comparing

alternatives on one or more criteria and thus do already have the skill of going through the decision-making procedure – apart from the use of some specific procedure-related terminology. However, what still has to be learned is the conceptual input into the decision-making procedure: knowledge about the relevant environmental criteria and specific issue knowledge in terms of the criteria-related properties of packages and packaging materials. Moreover, what is desired somewhere in the teaching/learning process is making the decision-making procedure explicit as a potentially useful tool for structuring their decision making and presenting their resulting argued point of view on other, new and complex issues. These points reflect the *educational aims* for the teaching/learning unit to be developed.

Teaching/learning process – After having established *what* should be addressed in the teaching/learning process, the next question then is one of *how* this should be done. The ideas about a *problem-posing approach* reflect a teaching/learning process that, on the one hand, is largely guided (from below) by the students' own motives, knowledge and questions in a problem-posing way, so that preferably they themselves frame the questions that drive their learning process, and, on the other hand, is structured (from above) by a sequence of interrelated teaching/learning activities, which starts from a proper interpretation of the students' pre-knowledge and skill and carefully develops their motives, knowledge and questions as intended, given the educational aims. For the practical purpose of designing such a teaching/learning process, the following sequence of five interrelated teaching/learning phases seemed to be useful for, at least, the topic under consideration: *motivation*, *question*, *investigation*, *application* and *reflection*. The resulting teaching/learning process has been outlined in chapter 3 and further elaborated in chapter 4.

The teaching/learning process starts off in the motivation phase by connecting to the students' assumed motive of wishing to contribute to 'a better environment', in order to induce a sense of purpose for at least beginning to study the topic and to provide them with a first sense of direction concerning their prospective learning process. By identifying personal environmental decision-making situations and their similarities the students come to realise that decision making about packages might also bear relevance to decision making about other environmental issues, such as those related to the use of water and energy. The teaching/learning process continues in the question phase with making the students become aware of a *need for extending their issue knowledge*. This phase starts with summoning and structuring the students' pre-knowledge by having them construct a concept network of the waste issue. Next, this structured body of general issue knowledge is used productively by asking the students to identify the two environmental criteria of depletion and pollution relevant for decision making about packages. After having established the environmental criteria in this way, the students are presented with a decision-making situation about packages and are asked to compare the packaging alternatives on these environmental criteria. Based on the assumed lack of specific pre-knowledge about the criteria-related properties of packages and packaging materials, it is expected that this task of comparing will summon quite a number of instances

of disagreement between students or of simply not knowing. These instances can then be turned into questions for further investigation about the criteria-related properties of packages and packaging materials, that further drive the students' learning process. This (roughly) reflects the problem-posing character of the teaching/learning process: the students' questions for further investigation are summoned in the context of the decision-making situations identified at the start – the same situations as those in which the answers to their questions will have to be applied at some later stage. The teaching/learning process logically continues with having the students extend their specific issue knowledge in the investigation phase. In the application phase this is, again logically, followed by having the students use their extended specific issue knowledge *for the purpose it has been extended for*: decision making about packages – first in the situation already encountered, and after that in self-identified situations. The students' reports on their decision making can then be used productively to learn about *presenting an argued point of view* as required by the attainment targets. Finally, the teaching/learning process is concluded by making the decision-making procedure and the required knowledge input into this procedure explicit, followed by a reflection on the tentative usefulness of this meta-cognitive decision-making tool for dealing with other environmental issues as surmised at the start of the teaching/learning process.

Teaching style – The teacher's task is one of carefully guiding the whole-class discussions in which the students put forward their ideas developed during the preceding small-group work on each of the tasks in the student materials. In performing this task the teacher has to find a balance between a proper interpretation of what the students put forward and the intended course of the teaching/learning process set out by the scenario. Moreover, the teacher's task is one of making this process explicit, so that the students are 'constantly' aware of why they are learning what. It was expected that thoughtfully reading and discussing the scenario and associated student materials would be an adequate preparation by the teacher on performing these tasks.

The still hypothetical didactical structure and its elaboration in terms of a scenario and student materials could, in the context of this thesis, be considered as the first product of extending our didactical knowledge about a problem-posing approach to teaching decision making about the waste issue. A product, however, that still has to be put to the test in order to acquire the required empirical support. A product, therefore, that has to be applied 'in situations the knowledge was extended for'. That is, classroom practice …

Application phase

The fourth phase of a problem-posing teaching/learning process has the didactical function of *applying this knowledge in situations the knowledge was extended for* – as must have become clear from the above-given description of the hypothetical topic-specific didactical structure.

The classroom testing of the teaching/learning unit (and therefore the underlying didactical structure) is described in chapters 5 and 6 of the thesis, dealing with the trial of the unit's first and second (or 'final') version, respectively. Again, for the sake of clarity, both chapters will be summarised in combination. Both classroom trials concerned just one teacher, teaching just one of his classes of target population students. The rationale for such a small-scale trial is that a large-scale trial would only be useful after having established that the hypothetical teaching/learning process at least has some *empirical support*. Or, in other words: that the design of the intended teaching/learning process is 'good enough' for the practical purpose of classroom teaching and has got over initial 'infants' diseases' that might confuse the interpretation of large-scale trial results.

The question of whether the design is 'good enough' is answered by comparing the intended and expected teaching/learning process as described to reasonable detail in the scenario with the observed classroom practice. Major deviations from the lines set out by the scenario represent points of on-trial or post-trial reflection. The results with respect to the earlier-mentioned three key features of the hypothetical teaching/learning process could be summarised as follows.

Knowledge and skill – The assumption about the students' general pre-knowledge about the waste issue has proven to be largely correct. This has been gathered during both trials from the observation of classroom practice: as expected, the students had no difficulty to construct the waste issue's concept network. It also appeared that students experience no difficulty in using a criteria format for decision making and in making the decision-making procedure explicit.

Teaching/learning process – The evaluation of the classroom trial of the unit's first version did reveal a number of *structural design errors* concerning the global motive, the relationship between issue knowledge and decision making, and the reflection on decision making. The motivation and question phases did not clearly enough communicate the overall intention of the teaching/learning process. That is, the decision-making context of 'learning more about waste' was not sufficiently emphasised. Therefore, neither the global motive nor the environmental criteria nor the relevance of the formulated questions for further investigation did become clear. Moreover, in the application phase of the teaching/learning process the attention paid to a clear and complete presentation of an argued point of view left to be desired. In short, the design of the teaching/learning process showed too little coherence – a deficiency that was, of course, addressed during the revision of the unit.

The classroom trial of the unit's improved second version (as fully described in chapter 4) showed that in the unit's question phase the students had no difficulty to establish the intended environmental criteria (depletion and pollution) for decision making about packages, but did experience difficulties in comparing packaging alternatives on these criteria. As a result, the expected questions for further investigation about the criteria-related properties of packages and packaging

materials did emerge in the context of decision making. This conclusion can be drawn, even though the observed classroom practice did not exactly follow the lines set out by the scenario. Quite a lot of what according to the scenario was supposed to happen did actually happen, but in the wrong order. By retrospectively using a method of *reconstruction* in order 'to make the best out of what actually happened in classroom practice' it is concluded that the design of the first part of the problem-posing teaching/learning process is now potentially 'good enough'. But then things started going more seriously off-track. In their investigation the students did find the intended answers to their questions – at least, so it seemed. When asked to apply their thus extended specific issue knowledge to decision making in the unit's application phase, a serious mismatch between the information in the reference materials and the students' perception of pollution through dumping and burning of packaging materials became apparent. The result was an unexpected classroom controversy over the reliability of the reference materials as far as these qualify the dumping and burning of packaging materials as not causing (much) pollution. This controversy might have been solved by recognising the students' pre-knowledge about pollution through dumping and burning household waste as largely correct and by addressing the difference between household waste and packaging waste. However, this did not take place. Therefore, the discussions about the results of the students' decision making were quite confusing. An explicitation of a complete and correct comparison of the packaging alternatives on each of the two environmental criteria, that is, a *content standard* for an argued point of view, was lost in the confusion. The same went for developing a *presentation standard* based on the argued points of view put forward by the students about their self-identified decision-making situations: a clear presentation of the alternatives and criteria, a systematic presentation of the comparison of these alternatives on these criteria, and an explicit presentation of the necessary weighting of comparisons and the resulting 'final' decision. In summary, there was a clear *stagnation* in the teaching/learning process. A stagnation that, in retrospect, is reflected by a lack of clarity in the scenario, both with respect to the purpose of the tasks concerned and with respect to a procedural specification for these tasks. However, by retrospectively using a method of *reformulation* in order to interpret the students' factual utterances in an appropriate way it is concluded that it could have been possible to develop and make explicit both the content and the presentation standard for an argued point of view, provided that the 'knowledge problem' was already solved in a satisfactory way. The identified stagnation, of course, had some repercussions in the unit's reflection phase. Nevertheless, the students were able to make the decision-making procedure and its required knowledge input explicit to quite some extent, and seemed to recognise the possibility of transfer to other environmental decision making.

In the evaluation of the teaching/learning unit through a post-trial questionnaire it appeared that also the students seem to have perceived a loss of coherence at roughly those points where the observed classroom practice appeared to considerably deviate from the lines set out by the scenario or where the scenario did not clearly outline the path to be taken (that is, in the question phase and in the

reflection phase of the unit, respectively). The students' perception of coherence at the point where the scenario is clearly deficient (that is, in the unit's application phase) was the exception to this 'rule', which might be explained by withholding appropriate feedback on the quality of their input into the teaching/learning process. From the data gathered through a post-trial content test it might be concluded that the still disappointing learning effects concerning the presentation of an argued point of view are in line with the observed stagnation in the application phase of the teaching/learning process.

Teaching style – During the first trial the teacher at times had considerable difficulty to refrain from falling back into his traditional role of 'transmitter of knowledge', to avoid a too hasty interpretation of what students were putting forward during the whole-class discussions, and to make the teaching/learning process transparent to the students. Therefore, selected instances of good and not-yet-so-good teaching practice have been used to prepare the teacher for the second trial. This was much appreciated by the teacher, as getting useful feedback on his teaching style was something he had never before experienced in his teaching career. During the second trial this reflection on teaching practice has proven to be effective to quite some extent. However, the teacher (still) experienced some difficulty in 'following' the intended teaching/learning process as set out in the scenario. At times he took the 'prescriptions' for teaching practice in the scenario far too rigidly, which caused a strained whole-class discussion in which what students put forward was not really addressed. On other occasions the scenario seemed to be completely forgotten, which caused the intended teaching/learning process to go off-track. This represents a dilemma. On the one hand, the scenario has been a valuable instrument for guiding the design of the teaching/learning process and an appropriate teaching practice. On the other hand, the scenario's 'prescriptions' do seem to influence the teacher's flexibility in dealing with the students' input into this process in a somewhat negative way. It is hoped that this dilemma can be solved by a further reflection on teaching practice.

The conclusion can be that the empirical support gathered from classroom practice is strong enough to consider the teaching/learning unit (and its underlying didactical structure) 'good enough' after some specified fine-tuning and revision of the scenario will be done.

Reflection and meta-cognition phases

According to chapter 7 in the thesis, the final phases of a problem-posing teaching/learning process have the didactical functions of *creating, in view of the global motive, a need for reflection on the skill involved* and *developing a (still possibly contextualised) meta-cognitive tool for an improved performance of this skill*.

From the above-given summary of the results of the classroom trials it follows that especially this part of the teaching/learning process is in need of revision. What is needed, is to make students reflect on their decision-making skill for the purpose

of a clear *presentation* of an argued point of view, and a subsequent development of a meta-cognitive tool for an improved performance of this skill (that is, a *presentation standard* for an argued point of view, e.g., in terms of a set of heuristic rules). In chapter 7 this is identified as one of the points on which didactical progress has been made in this study.

The two phases just discussed in connection with the topic of decision making about the waste issue can also be discussed in the context of the developmental research reported in this thesis. The skill involved then relates to the ability of designing a problem-posing teaching/learning process. In chapter 7, the designed problem-posing approach to the teaching/learning about decision making on the waste issue is reflected upon. It is characterised as a teaching/learning process that naturally switches between issue knowledge and decision-making skill, driven by the content-related motives that are developed. This didactical structure could be seen as a still *contextualised meta-cognitive tool* for an improved performance of designing and testing other teaching/learning units about comparable topics. A further step is taken in an attempt to *decontextualise* this tool. The result is a problem-posing, level-structured didactical structure for the interrelated teaching/learning of knowledge and skill in terms of the six teaching phases used throughout this summary. The core of this didactical structure could be described as bringing the students in such a position that, guided by the design of the teaching/learning activities, preferably they themselves first come to pose and want to solve a 'knowledge-related problem in the context of a skill-related issue by reflecting on the use of the existing knowledge' and at a later stage come to pose and want to solve a 'skill-related problem by reflecting on the use of the existing skill'. Chapter 7 is then concluded by tentatively exploring the usefulness of this generalised didactical structure for further developmental research in the areas of teaching decision making and of teaching other complex intellectual skills such as problem solving.

IVLOS *Interfacultair Instituut voor Lerarenopleiding, Onderwijsontwikkeling en Studievaardigheden*