Designing and validating a didactical structure for a problem-posing approach to teaching decision making about the waste issue

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Abstract

In a science-technology-society approach to science education, decision making is one of the consistently emphasised skills. This implies that science knowledge should help students in their decision making about science/technology-related social issues. About a decade ago the *Centre for Science and Mathematics Education* (Cdβ) at Utrecht University decided to start a small-scale research study with the aim of addressing this topic: just what might this 'decision making' mean, how to teach/learn it, and what to expect of it in a target population of grade 8, middle-ability students?

This paper will briefly outline the motives for undertaking this study, and more extensively address its method of *developmental research* and its product in terms of an empirically based topic-specific *didactical structure* – with a focus on the design of the teaching/learning sequence and its classroom test.

Introduction

The aim of the study was to develop and validate a didactical structure for the teaching/learning of decision making about the waste issue, reflected by its four-fold research question: what does such a didactical structure look like, what is expected of it in classroom practice, what happens in actual classroom practice as compared to what is expected, and which indications for its improvement does that offer?

A motive for undertaking this study can be found in three 'movements' in Dutch secondary education over the past decades: the emergence of *science, technology and society education* (Eijkelhof & Kortland, 1988) 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: the students 'are able to present an argued point of view in decision-making situations'. However, the (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 (Fleming, 1987; Eijkelhof, 1990; Ratcliffe, 1997). 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* (Ogborn, 1997) 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. The constructivist teaching/learning strategies of the 1980s that deliberately employ cognitive conflict (Duit & Treagust, 1998), 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 (Klaassen & Lijnse, 1996). 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 for the interrelated teaching/learning of knowledge and skill provided a second broad motive for undertaking the study.

This paper intends to summarise the way in which the study was carried out and the main results, without going into empirical details. The full report of the study has been published elsewhere (Kortland, 2001).

Developmental research

The character of the study is one of *developmental research*. The reason for adopting this type of research has to do with the study's *aim* of arriving at an empirically based topic-specific didactical structure. The purpose of this section is to indicate this relationship between aim and research method, and to focus on the use of a *scenario* as an instrument for *validating* the designed teaching/learning sequence.

Aim – The aim of the study was to develop and validate a *didactical structure* (Lijnse, 1995) for the teaching/learning about the topic chosen: *decision making* about the *waste issue*, limited to *packaging waste*. Such a didactical structure encompasses the didactical starting-points and a related global outline of the teaching/learning process. These didactical starting-points could be summarised as an approach to teaching/learning starting from a *proper interpretation* of the students' existing issue knowledge and decision-making skill as being coherent and sensible (Klaassen & Lijnse, 1996), and using these productively to have them arrive at the very ideas one wants to teach through a *problem-posing teaching/learning process* which is largely driven by starting from and further developing the students' own, content-related motives (Klaassen, 1995).

Designing such a didactical structure is a topic-specific activity, asking for an empirical process of closely interconnected research and development: *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: a didactical structure. A critical element in such a process is the use of a *scenario* for designing the sequence of specific teaching/learning activities, for preparing the teacher on the classroom trial, for focusing the classroom observations during the trial, and for guiding the post-trial reflection on the question whether or not the designed didactical structure could be considered 'good enough'. Such a scenario can be seen as an extensive, explicit description and justification of the intended and expected teaching/learning process in classroom practice.

Scenario – 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. The result of this first step would be a *hypothetical* didactical structure.

The second step 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 assumption about the outcomes of each task. These assumptions 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 and/or classroom trials of a preceding version of the teaching/learning unit). In writing the scenario and the student materials these assumptions 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 classroom practice. However, this is not to say that in classroom practice the teaching/learning 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 the students' 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.

The scenario not only provides valuable material for the teacher in preparing for the trial, but also plays a crucial role in *validating* the designed teaching/learning sequence.

Validation – The pre-trial development of a scenario allows a comparison to be made between the intended and expected teaching/learning process as described in the scenario and the actual teaching learning process as observed in classroom practice. As long as classroom practice shows no major deviations from the scenario, the teaching/learning unit and its underlying didactical structure could be considered 'good enough'. Observed major deviations from the scenario, however, represent serious points for reflection: where exactly 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 or she was supposed to do or say, etc. Such a reflection addresses deficiencies in the *elaboration* of the didactical structure in terms of a necessary fine-tuning or even considerable revision of the scenario and student materials, without yet doubting the adequacy of the underlying didactical structure. It is only when 'repairing' the observed major deviations from the scenario by such fine-tuning or revision does not seem possible, that the didactical structure itself should be considered in need of rethinking.

The above points at the necessity of an in-depth, small-scale and qualitative observation and analysis of classroom practice. This was done during two complete cycles of developmental research, featuring two successive experimental groups of target-population students at the same school and taught by the same teacher. This was considered to be enough to provide sufficient empirical support 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 would become 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 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 'infants' diseases' muddling the interpretation of research findings. Moreover, the experiences during the preceding cycles of developmental research can then be used productively for adequately preparing the trial teachers for this further testing of the product.

The design: a hypothetical didactical structure

This section will describe the design of the hypothetical didactical structure and its elaboration into a teaching/learning unit (as a combination of a scenario and student materials), 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 – The construction of the didactical structure started with identifying an appropriate conceptual network of the waste issue and an adequate decision-making procedure, followed by interpreting the students' existing issue knowledge and decision-making skill in these respects.

For reasons of limited teaching time and the characteristics of the target population, the waste issue was limited to discarded packages in household garbage while the energy aspects of packaging and waste processing were not taken into account. The structure of the thus limited waste issue, emerging from an analysis of a number of Dutch national research and policy documents on waste management, is reproduced in figure 1. This model 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.

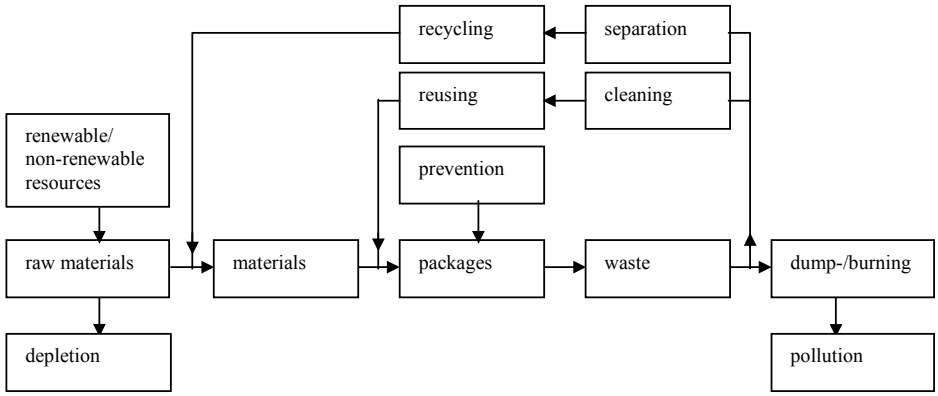

Figure 1 – A model of the waste issue, limited to household packaging waste.

An adequate decision-making procedure, emerging from an analysis of the decision-making literature, was thought to be the one reproduced in figure 2: 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 (e.g., Carroll & Johnson, 1990; Gouran & Hirokawa, 1996). Such a procedure is also 'widely' used in education – that is, in those few cases in which decision making is explicitly addressed in an educational setting (Baron & Brown, 1991). 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.

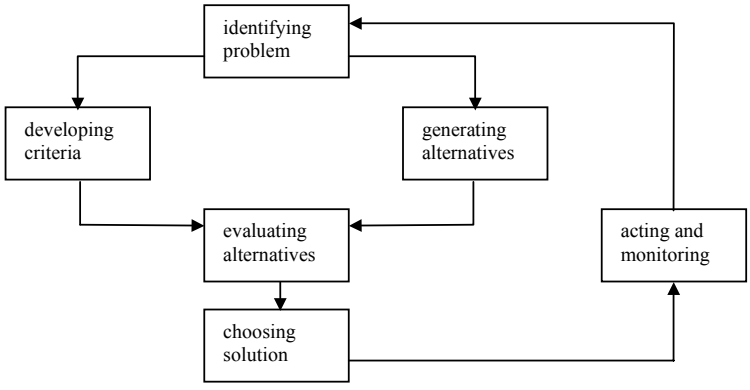

Figure 2 – A model of a decision-making procedure.

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. In the exploratory phase preceding the actual research study, interviews with students and lesson observations gave rise to a characterisation of students' pre-knowledge and decision-

making skill in term of an ‘incomplete perception of the general structure of the waste issue’, a ‘confused and incorrect use of specific waste-related concepts’ and – partly as a result of that – a ‘superficial decision making’ (Kortland, 1996; 1997). With hindsight, these negative qualifications could largely be retraced to shortcomings in the interview strategy and the teaching materials used at that time. Therefore, at the start of the actual research study a more positive position was taken: what might reasonably be expected of the students’ knowledge about the waste issue and their decision-making skill. Concerning their waste issue knowledge this results in taking the position that they 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, now 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 inter-pretation of the students’ pre-knowledge and skill and carefully develops their motives, knowledge and questions as intended, given the educational aims. 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: *motivation*, *question*, *investigation*, *application* and *reflection*. The resulting global outline of the teaching/learning process is represented by figure 3.

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, guided by a puzzle format of the task. The puzzle’s solution reflects the model of the waste issue of figure 1, although not in such a schematic form. Next, this structured body of general issue knowledge is used productively by asking the students to identify the two environmental criteria (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.

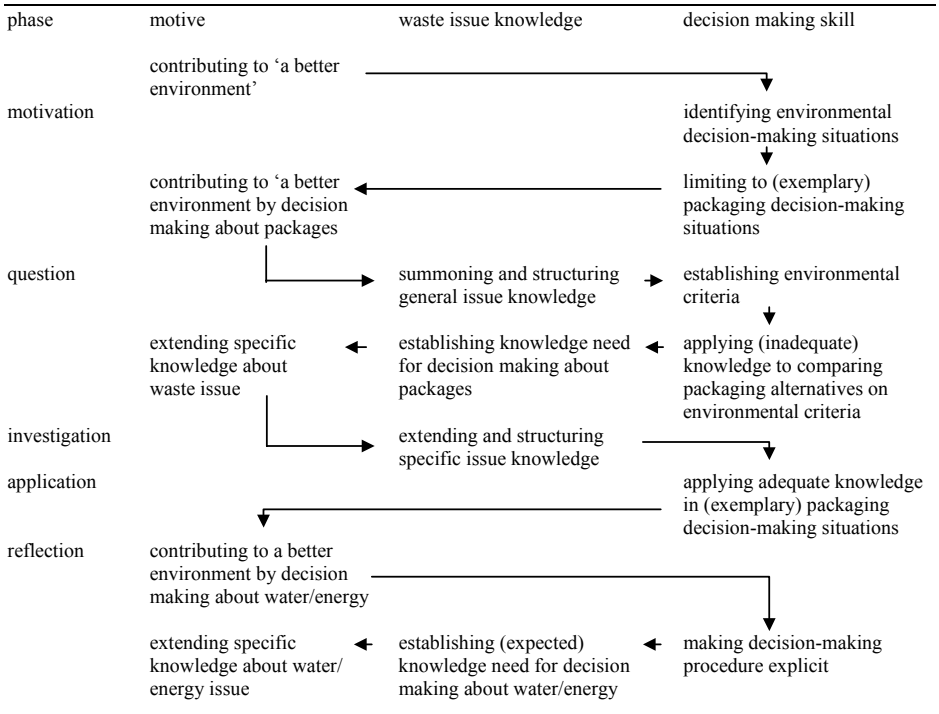

Figure 3 – A (hypothetical) didactical structure for the teaching/learning of decision making about the waste issue, indicating the interaction between the students' existing and developing motive, issue knowledge and decision-making skill.

The teaching/learning process logically continues with having the students extend their specific issue knowledge in the *investigation phase* by studying reference materials, performing experiments and conducting interviews. 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 in the *reflection phase* by making the decision-making procedure and the required knowledge input into this procedure explicit, again guided by a puzzle format of the task. The puzzle's solution reflects the model of the decision-making procedure of figure 2, although not in such a schematic form. This is then followed by a reflection on the tentative usefulness of this metacognitive decision-making tool for dealing with other environmental issues as surmised at the start of the teaching/learning process.

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*.

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.

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. During the first two phases in 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.

This seems to be an important difference with the few other attempts to incorporate decision making in science education at classroom level, such as the one by Ratcliffe (1997). In her approach a decision-making task with an explicit general structure (roughly comparable to the decision-making procedure in figure 2) 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. 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 the study presented in this paper. For in this way, the students then know *why* this knowledge is being acquired by them.

Teaching style – The teacher's task is difficult to understand without having an idea about the character of the student materials. These materials exclusively consist of tasks made up of a brief introduction followed by open-ended questions, without any connecting explanatory storyline in between the tasks. The teacher's task is then 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. This means that the teacher is expected to show the coherence of the 'local' teaching/learning process by making a transition between two successive tasks on the basis of what the students have been putting forward in one task in the light of the purpose of the next task. A comparable task of the teacher concerns the 'global' teaching/learning process, to be performed by stimulating the students at specific points to reflect on why what has been done so far and to speculate on why what will be done next. The start and the end of each of the five phases in the teaching/learning process, because of their coherence and distinct didactical purpose, would provide 'natural' points for doing this.

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 test: validating the didactical structure

The still hypothetical didactical structure and its elaboration in terms of a scenario and student materials could be considered as the first product of extending our didactical knowledge about a problem-posing approach to teaching decision making about the waste issue – and possibly, more in general, about the interrelated teaching/learning of knowledge and skill. A product, however, that still has to be put to the test in order to acquire the required empirical support. As mentioned earlier, the question of whether or not 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. 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 – During the classroom trial of the teaching/learning unit the motivation phase and part of the question phase went roughly as planned in the scenario. It appeared that in the 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. The observed classroom practice, however, appeared to considerably deviate from the lines set out by the scenario. Although quite a lot of what according to the scenario was supposed to

happen did actually happen, it happened in the wrong order. By retrospectively using a method of *reconstruction* (Kortland, 2001, pp. 120-127) it was tried 'to make the best out of what actually happened in classroom practice'. This involves cutting and pasting of what has actually happened 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.

On the basis of the comparison between scenario and classroom practice it was concluded that the design of the first part of the problem-posing teaching/learning process is *potentially* 'good enough'. Potentially, because the empirical support from the classroom trial partly consists of a reconstruction of the teaching/learning process along the lines set out by the scenario – and moreover, a reconstruction that in some aspects is still incomplete.

From then on things started going a bit 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. 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, could be traced back to 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* (Kortland, 2001, pp. 140-150) in order to interpret the students' factual utterances in an appropriate way it was again tried 'to make the best out of what actually happened'. This implies that the student's utterances, if necessary, are 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 schematic reproduction of what the student, according to the reader or listener, intends to express with his/her factual utterances, and forms the basis for giving feedback on the content and/or presentation of the student's argued point of view. It was concluded that, by giving such adequate feedback, it would 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' concerning pollution through dumping and burning packaging waste would have been solved in a satisfactory way. The identified stagnation in the teaching/learning process and lack of clarity in the scenario, 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.

From the identified stagnation in classroom practice and the scenario's lack of clarity the conclusion was drawn that the second part of the problem-posing teaching/learning process is 'not yet good enough', and that some specified fine-tuning and revision of the scenario and its underlying didactical structure would be necessary. The empirical data, however, were considered strong enough to speculate with quite some confidence that in this way it would be possible to arrive at a 'good enough' design.

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 and a growing experience in using the teaching/learning unit. However, the question is whether a scenario developed for research purposes could also serve as a teacher's manual, as has been the case in this study. A question which, at least for the time being, cannot be answered affirmatively. Reading and discussing the scenario and the accompanying student materials, whether or not in combination with an incidental reflection on classroom practice, constitutes an insufficient preparation of the teacher on performing the required tasks (Joyce & Showers, 1988).

Reflection and extrapolation

The pre-trial development of a scenario did allow a comparison between the intended and expected teaching/learning process as described in the scenario and the actual teaching learning process as observed in classroom practice. As far as classroom practice did show no major deviations from the scenario, the teaching/learning unit and its underlying didactical structure could be considered 'good enough' for practical purposes – that is, teaching practice. By reflecting on occurring major deviations it has been possible to identify those parts of the teaching/learning unit and its underlying didactical structure that are still in need of some fine-tuning or even considerable revision to improve on the effectiveness of the teaching/learning process, and to even identify the character of the necessary revisions and to arrive at a more articulate expression of the 'final' didactical structure. The purpose of this section is to outline this 'final' *didactical structure* and to speculate about its *extrapolation* in the context of further developmental research.

Didactical structure – The developmental research did yield indications for a necessary fine-tuning and revision of the scenario and its underlying didactical structure. A major point in this revision concerns the *reflection phase* of the teaching/learning process which should – in hindsight – focus on creating a need for reflection on the students' decision-making skill (that is, their *presentation* of an argued point of view), resulting in another content-related motive that would further drive the students' learning process towards developing a metacognitive tool for regulating and controlling the cognitive steps in a

decision-making process – in this case a content and a presentation standard for an argued point of view. This would mean that application of the knowledge acquired during the investigation phase will trigger the students to pose a new question about the 'requirements' they themselves would set for the content and presentation of their argued point of view. Such a question does not emerge by itself, but can be formulated in interaction between teacher and students by reflecting on the argued points of view presented by the students. Such a reflection would produce the building blocks for the intended standards. This revision of the didactical structure not only strengthens the problem-posing character of the teaching/learning process, but also the coherence of the two teaching/learning processes aimed at learning to present an argued point of view – as 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.

The final version of the didactical structure is presented in figure 4, showing the two coupled, interrelated and mutually dependent teaching/learning processes.

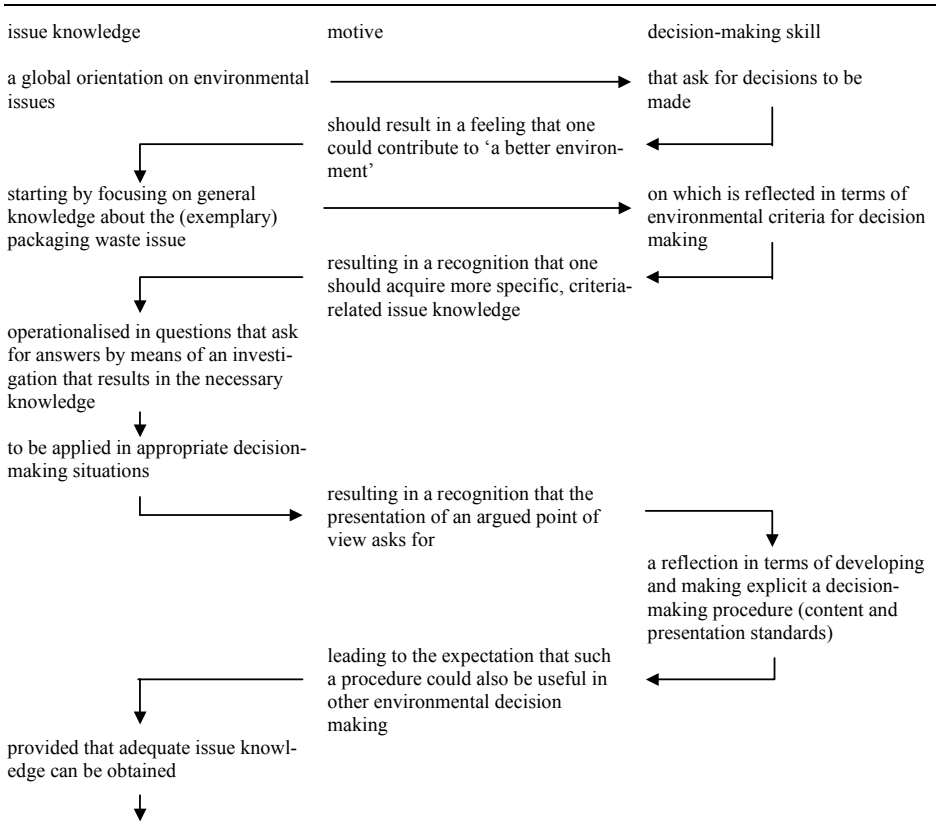

Figure 4 – A summary of the didactical structure for a problem-posing approach to the teaching/learning about decision making on the waste issue.

On the basis of the empirical data collected so far it can be hypothesised with quite some confidence that this modified didactical structure and an accordingly improved scenario will make the teaching/learning process proceed as intended in a follow-up larger scale testing, 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. However, one further issue has to be addressed. The topic-specific didactical structure for decision making about the waste issue 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 or not 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'. In an elaboration of the modified didactical structure 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.

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 hinted at in figure 4. 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 metacognitive tool that helps the students to regulate and control the cognitive steps to be taken in such a process.

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 complex intellectual skills as well – such as the skill of problem solving, in which the interaction between a knowledge base and a collection of heuristic rules also plays an important role (Perkins & Salomon, 1989).

Such extrapolations, however, ask for a *generalisation* of the topic-specific didactical structure as developed in the context of this study – a (speculative) generalisation as presented in figure 5. This three-column scheme shows in very general terms how the teaching/learning process switches between the acquisition of knowledge and skill, and that these switches seem to come rather naturally forward because of the content-related motives that are developed. Moreover, the scheme of figure 5 triggers a description of the teaching/learning process in terms of a number of phases, each having a specific didactical function (Lijnse, 2000):

- Motivation phase – orienting and evoking a global interest in and motive for a study of the topic at hand.
- Question phase – narrowing down this global motive into a content-specific need for more knowledge.
- Investigation phase – extending the students' existing knowledge, in view of the global motive and the more specifically formulated knowledge need.
- Application phase – applying this knowledge in situations the knowledge was extended for.
- Reflection phase – creating, in view of the global motive, a need for a reflection on the skill involved.

- Metacognition phase – developing a (still possibly contextualised) metacognitive tool for an improved performance of this skill.

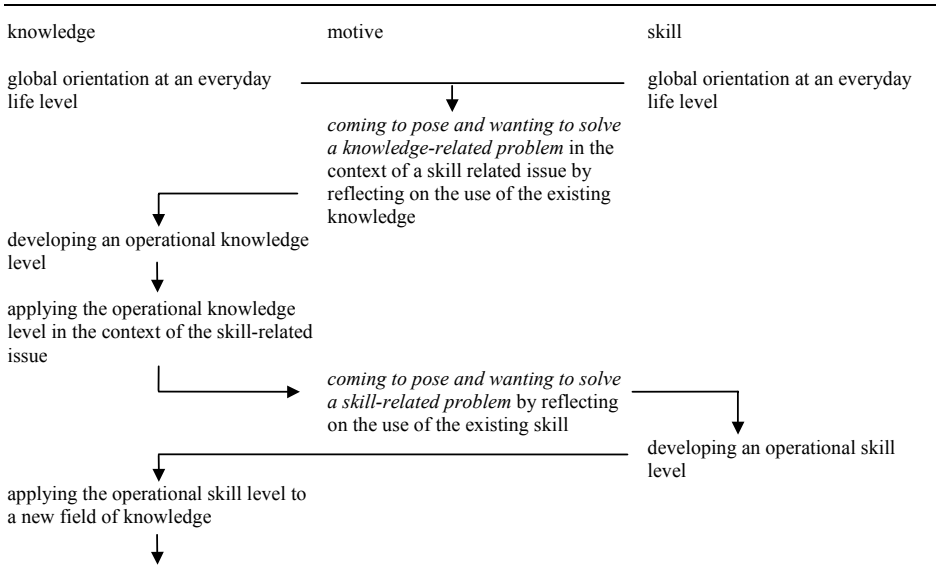

Figure 5 – A summary of the speculative didactical structure for a problem-posing approach to the interrelated acquisition of knowledge and skill.

Such a phase sequence – of which the labels are still tentatively formulated – can be recognised to some extent in other examples of a problem-posing approach to teaching specific topics (Klaassen, 1995; Vollebregt, 1998). This strengthens the expectation that the generalised didactical structure of figure 5 can play a role in on-going and future developmental research.

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References

Baron, J. & R.V. Brown (Eds.) (1991), *Teaching decision making to adolescents*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Carroll, J.S. & E.J. Johnson (1990), *Decision research – A field guide*. London: Sage Publications.

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.

Eijkelhof, H.M.C. (1990), *Radiation and risk in physics education*. Utrecht: Cdβ Press.

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.

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.

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.
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.
Kortland, J. (1996), An STS case study about students' decision making on the waste issue. *Science Education, 80* (6), 673-689.
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. (2001), *A problem-posing approach to teaching decision making about the waste issue*. Utrecht: Cdβ Press.
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.
Ogborn, J. (1997), Constructivist metaphors of learning science. *Science & Education, 6*, 121-133.
Perkins, D.N. & G. Salomon (1989), Are cognitive skills context-bound? *Educational Researcher, 16*, 16-25.
Ratcliffe, M. (1997), Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education, 19* (2), 167-182.
Vollebregt, M.J. (1998), *A problem-posing approach to teaching an initial particle model*. Utrecht: Cdβ Press.