3 Conditions to escape from and to escape to

In Chapter 2, I have arrived at a description of the rigid and isolated structure of the currently dominant school chemistry curriculum. Subsequently, I have explained the structure of, what I call Dominant School Chemistry in terms of the concept of *Normal Science Education*. Finally, I have argued that this state of affairs is undesirable, if and when a general aim such as 'Chemistry for All' is to be met.

In this chapter I begin by summarizing the argument so far by giving brief answers to research questions 1, 2 and 3 as they have been listed in Figure 3.1 (section 3.1). After this introductory section, I focus in this chapter on question 4: "What are the conditions for escape?" in order to arrive at a first description of the *necessary* conditions for escape.

A brief review of some attempts to reform the dominant school science curriculum, in terms of the concept of Normal Science Education provides an idea of the many difficulties involved when trying to realize a desirable reform, that is, to escape from Dominant School Science. An analysis of reasons for the difficulty to escape from Dominant School Chemistry, given its rigid and isolated character, leads then to the first condition for escape which has to do with the structure of the dominant school chemistry curriculum (section 3.2).

A discussion of the concept of *curriculum emphasis* developed by Roberts (1982), a concept which functions as a "view affording" lens on the nature of science curricula, leads us to two other conditions for escape. The second condition concerns the development of a vision on new science curricula, while the third has to do with the method one *chooses* to escape from Dominant School Science (section 3.3).

Finally, I discuss some problems with the implementation of new curriculum emphases, and the relationship between the concept of curriculum emphasis and the concept of Normal Science Education. I also discuss the three conditions of escape in connection with the concept of *developmental research*, which combines systematic research with strategies for development of innovative science curricula (section 3.4).

Chapter 3 sets the stage for the following two chapters, in which is given a detailed analysis of my evaluative research into the innovative attempt by the Salters' Chemistry Project to escape form Dominant School Chemistry as it existed in England in the 1980s. In Chapters 4 and 5 the focus is on the Project's vision, its method, and the resistance it met. In Chapter 6 I come back to the three conditions for escape and the concept of developmental research in light of my empirical findings on the development and realization of the Salters' Chemistry curriculum.

3.1 To escape from Dominant School Chemistry

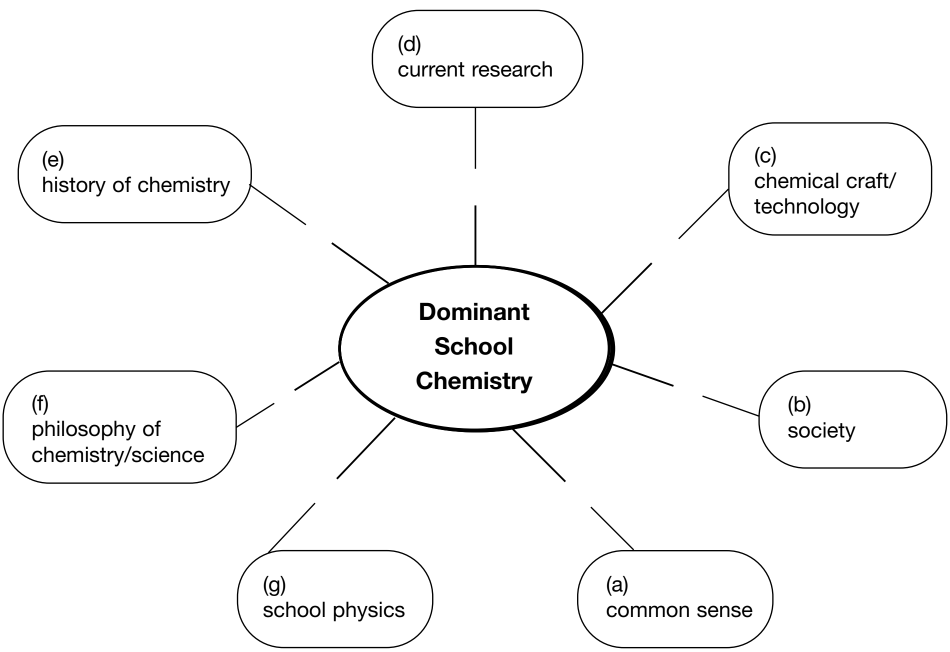
The research questions I am trying to answer in this thesis (first listed in Figure 1.6) are reproduced in Figure 3.1 below. The first three questions have been answered in Chapter 2, while the last three questions will be dealt with in Chapters 4, 5 and 6. The question which concerns us in this chapter is question 4: "What are the conditions for escape?"

Figure 3.1 Research questions

1. What is the structure of the current school chemistry curriculum?
2. Why is this structure the way it is?
3. Is this structure a desirable structure?
4. What are conditions for escape?
5. To what extent does the Salters' Chemistry curriculum escape from this structure?
6. Why is it so hard to escape from this structure?
7. How can attempts to escape from this structure be more successful?

Let me first give a short summary of the answers to the questions 1, 2 and 3, as discussed in Chapter 2. As argued in Chapter 2, the currently dominant school chemistry curriculum has to be taken as a rigid combination of a specific substantive structure based on corpuscular theory, a specific philosophical structure called educational positivism, and a specific pedagogical structure involving initiatory and preparatory training of future chemists. Whereas this first general feature, its *rigidity*, characterizes the *internal* structure of dominant school chemistry, the second general feature, its *isolation*, characterizes the external relations, or rather the lack of them, of dominant school chemistry with other domains or fields (Figure 3.2).

Figure 3.2 Sevenfold isolation of Dominant School Chemistry



The strong similarities between the substantive, philosophical, and pedagogical structures of Dominant School Chemistry (DSC) and Normal Science Education (NSE) lead to the conclusion that DSC must be considered as a form of NSE, in this case the form is Normal Chemistry Education. Dominant School Chemistry has a curriculum structure serving similar functions to those of Normal Science Education, namely to initiate and prepare pupils at the secondary level for scientific training. This means that Dominant School Chemistry has a pre-professional curriculum structure like that of Normal Chemistry Education as it is usually practiced at the tertiary or university level. Furthermore, the Normal Chemistry Education concept explains why Dominant School Chemistry is an inappropriate or undesirable curriculum orientation for the majority of students who do not aim to study chemistry at the tertiary level.

The essential features of Dominant School Chemistry, rigidity and isolation, imply a number of undesirable consequences affecting students and teachers of school chemistry alike. The prevailing curriculum emphasis of Dominant School Chemistry, that is, of chemistry as a body of knowledge consisting of propositions and algorithms, gives a rather one-sided view of the rich activities of chemists perform in scientific research, technology, and society. Teaching school chemistry this way instills a dogmatic attitude to science. Furthermore, it appears that this mode of teaching is ineffective with regard to understanding chemistry as a science for the majority of students, and probably also in part for the minority of students who go on to study chemistry at university.

Finally, given the global consensus on a general aim for school chemistry, epitomized in the slogan "Chemistry for All", Dominant School Chemistry is surely inappropriate for the majority of students seen as future citizens, and maybe also inappropriate for the few who aim to be future students of chemistry. In brief, Dominant School Chemistry is ineffective as a means and largely undesirable as an end. This calls for the development – for the majority of students, if not for all, at the secondary level – of a new school chemistry curriculum which escapes from the currently dominant structure of the current school chemistry curriculum.

The first condition of escape

The revision of our initial hypothesis on the current structure of school chemistry, Coherent School Chemistry, leads to the formulation of a first condition of escape:

- Perform a domain-specific analysis of the structure of the currently dominant school chemistry curriculum, using the curriculum framework developed here.

In the process of developing a new school chemistry curriculum it is to be recommended to be aware of, anticipate, and avoid, or at least eventually deal with, any difficulties related to the currently dominant school chemistry curriculum and all curriculum levels involved. In other words, to take be necessary preventive or corrective measures in order to avoid marginal or superficial changes in the currently dominant school chemistry curriculum, changes such as the introduction of a new rhetoric of teaching or a new curriculum emphasis on top of Normal Science Education (NSE). In brief, while attempting a radical reform of school chemistry, we have to resist what I call the *NSE reflex*. In Chapters 4 and 5, while reviewing the attempt of the Salters' Chemistry Project to escape from Dominant School Chemistry, we will see this NSE reflex in action.

Thus, from the main findings of Chapter 2, the rigidity and isolation of Dominant School Chemistry and their explanation in terms of Normal Science Education, can be inferred specific measures on what *not* to do. That is, do *not* import the structure of Dominant School Chemistry in new curriculum projects, and take all necessary measures to prevent and/or correct this if it begins to happen. Having detailed knowledge about what *to escape from* enables those involved in a developmental project to reform school chemistry where to expect difficulties or points of resistance, and to take specific measures to prevent or at least deal with these difficulties if and when they are met.

It is to be noted, that these measures, derived from the first condition for escape, apply to all curriculum levels involved and to all curriculum actors involved at these levels, from the members of the steering group to the team of developers and teachers, and the researchers. For example, it will have implications for the selection, training, and coaching of the teams of teachers and developers who design and trial the new curriculum.

In section 3.2 I will review some of the past attempts to escape from Dominant School Science, and also from Dominant School Chemistry, in order to discuss, firstly, whether developers' lack of success in doing so can be attributed to a failure in fulfilling condition one, and secondly, whether curriculum reforms which did fulfill condition one succeeded, and if not, which other conditions should have been met in order to do so. This will bring us to a discussion in section 3.3 of two other conditions for escape, conditions having to do with the development of a vision and a method to escape from Dominant School Science, more specifically from Dominant School Chemistry.

3.2 A brief review of attempts to escape

There have been many attempts to change, by optimizing or reforming, the practice of traditional school science (what I have called here Normal Science Education) since this tradition came to prevail at the end of the 19th century (Layton, 1973; De Boer, 1991; Just, 1989). For example, in Chapter 2, several IF members mentioned Salters' Chemistry and ChemCom as examples in the 1980s of alternative Science, Technology and Society (STS) oriented curricula, while others mentioned Nuffield Chemistry and ChemStudy as examples of alternative History and Philosophy of Science (HPS) oriented curricula in the 1970s. The latter courses were part of the so-called structure-of-the-disciplines approach to science education. This has been the most systematic attempt to reform school science so far, often described as a curriculum wave that began in the USA in the early 1960s following the launching of Sputnik.

3.2.1 Appraisal of the structure-of-the-disciplines approach

The structure-of-the-disciplines approach to science curricula set itself the task to realize, in a new and better way, teaching students the understanding of scientific phenomena by way of:

– modernizing and sequencing the content of school science curricula along the lines of the structure-of-the-disciplines;

– developing new teaching and learning approaches, mostly forms of discovery learning and enquiry teaching (Bruner, 1960; Schwab, 1962).

In different ways the projected science curricula – for chemistry ChemStudy and CBA, for physics PSSC and Harvard Project Physics, and for biology the BSCS curricula in the Blue, Yellow, and Green versions – were meant to replace the unintended and unwanted reproduction of facts with meaningful understanding of scientific knowledge, theories, and methods. In particular, Schwab (1962, pp. 21-24) argued strongly against the "*teaching of science as dogma*", which he saw as the dominant tradition of school science teaching students science as "a rhetoric of conclusions". This tradition should be replaced, he felt, by a *teaching of science as enquiry* which would "show some of the conclusions of science in the framework of the way they arise and are tested" (Schwab, 1963, p. 23).

Despite the major efforts performed during the post-Sputnik curriculum wave which spread to many other countries, the results were rather disappointing. One major evaluation study said:

> In spite of new curricula, better trained teachers, and improved facilities and equipment, the optimistic expectations for students becoming inquirers have seldom been fulfilled (Welch, 1981).

Only a few curricula are mentioned as an exception, notably the Harvard Project Physics course and the Yellow version of the BSCS High School Biology course (Matthews, 1994, pp. 6,18). Science educators (Fensham, 1992; Duschl, 1993; Matthews, 1998) reviewing the evaluative research of these new curricula (new compared to the preceding traditional curricula) likewise concluded that students' understanding of science had not improved in a significant way. The reproduction of facts and methods still reigned and continues to reign, a conclusion confirmed for school chemistry by the research described in Chapter 2.

3.2.2 Factors involved in school science reform

Curriculum reform projects are very complex processes (Chapter 1), consisting of several curriculum levels (Goodlad) and curriculum categories (Schwab) in which many factors as well as actors are involved. Matthews (1994, p.18) said in this regard:

> Now in the 1990s, when school science reform is once more on the agenda, it is timely to know how much of this failure and confusion was due to the curriculum materials, how much to teacher inadequacies, how much to implementation and logistic factors, how much to general anti-intellectual or anti-scientific factors and how much to a residue factor of faulty learning theory and inadequate views of scientific method that the schemes incorporated.

It is to be expected that the factors attributed by researchers of science education to the failure of the structure-of-the-discipline curricula are many and diverse. In order to emphasize the *systemic* character of curriculum reform, I have categorized in Figure 3.3 the factors discussed below in relation to the (transition of) curriculum levels (described in section 1.3.1).

Firstly, in a recent publication Duschl and Osborne (2002) point to: (i) the misplaced goals of the actual projects: "final form" science instead of teaching science as inquiry;

(ii) resistance of science teachers because of their previous training (p. 62); and (iii) lack of theory of instruction which combines cognitive with social situation (p. 43). Duschl and Osborne also mention Novak (1977) who attributed the failure to a lack of theory of learning (p. 42). They see these factors as barriers which have to be overcome if, as they argue, the aim of science courses is to be "to engage [students] in argumentation, the construction of explanations and the evaluation of evidence" (p. 41).

Secondly, Aikenhead (2000), in a paper titled: "*Changes Need to Succeed Where We Previously Failed*", mentions some other points, namely (i) curriculum developers failed to involve teachers in policy making and developing; (ii) a failure to offer teachers "practical on sight experience" (p. 340); (iii) a general lack of research and development.

Figure 3.3 Factors of failure involved in science education reform

Curriculum levels	**Failure attributed to factor by author**
Visionary curriculum	• Misplaced goals (Duschl & Osborne 2002; Welch 1979) • Lack of involvement of teachers in policy making (Aikenhead 2000) • Inadequate views of scientific method (Matthews, 1994)
Designed curriculum	• Lack of consistency between vision and teaching materials [this thesis] • Texts do not reflect vision (Herron, 1971; Diederich, 1969) • Exercises do not reflect idea of enquiry ((Herron, 1970) • Lack of involvement of teachers in development process (Aikenhead 2000) • Lack of cognitive and social theory of instruction (Duschl & Osborne 2002) • Lack of theory of learning (Novak, 1977)
Formal curriculum	• Transformation of school science into proto-university science or the professionalization of school science (Matthews, 1994, p.16)
Interpreted curriculum	• Lack of consistency, vision, and in-service training (Herron, 1971) • Lack of "practical on sight experience" for teachers (Aikenhead 2000)
Taught curriculum	• Lack of consistency between vision and views of teachers [this thesis] • Resistance of teachers (Duschl & Osborne 2002, Herron, 1970)
Experienced curriculum	• Resistance of students • General lack of research and development (Aikenhead 2000)

Thirdly, Herron (1970), at the time a student of Schwab, evaluated a number of the newly developed curriculum materials, PSSC, ChemStudy, and BSCS *Blue version*, in order to:

> … determine the clarity and coherence with which the doctrine [i.e., teaching of science as enquiry] is set forth and to determine to what extent the doctrine is incorporated in the actual structure of the textual materials (ibid., p. 172).

Herron found that the texts portray, in Schwab's terms, stable enquiry rather than fluid enquiry, that they fail to emphasize properly the "ideational" factor of science, and the self-corrective nature of science. Similar conclusions are reached by Diederich (1969).

As for enquiry-oriented exercises, only a few have been categorized as really open, while most are categorized as closed, that is, "problem area, methods of solution, and "correct" interpretations are given" (Herron, 1971, pp.197-203).

From the interviews of 60 teachers who were giving these courses at the time, Herron concluded that very few of them had an understanding of the theme of *science as enquiry* on the level of the textbook used, whether they had attended the teachers' institutes associated with the movement, or not. In fact, the lecture mode used by college specialists might have reinforced their traditional way of teaching at the expense of learning to teach science as enquiry.

Thus, the results of these curriculum projects (PSSC, ChemStudy, BSCS) were not consistent with the vision of teaching science as enquiry as reflected in the designed curriculum, in text or exercises, or in the interpreted curriculum by teachers.

Interestingly, Herron (ibid., p. 209) noted: "Ideally the present study should be followed up by an attempt to observe teachers in their classrooms and to identify and analyze whatever views of enquiry may or may not be entailed as logical consequences of their activities", that is, Herron suggested to perform an evaluation of the taught curriculum, as I will describe in detail for the Salters' Chemistry course in Chapter 5.

3.2.3 Relevance of the first condition of escape

Performing a domain-specific analysis of the structure of the dominant school science / chemistry curriculum (first condition of escape, mentioned in section 3.1) has relevance both prior to as well as integral to the actual development process. Regarding the latter, the preventive and corrective measures taken in accordance with the results of a domain-specific analysis are relevant to all curriculum levels depicted in Figure 3.3, or rather, they are relevant to all *transitions* of curriculum levels. Only extensive curriculum study can reveal if and to what extent curriculum projects such as PSSC, ChemStudy or BSCS did perform a domain-specific analysis of their respective science curriculum, and if and to what extent the developers were able to take appropriate measures. Even though not many curriculum projects were able to perform a detailed domain-specific analysis, it seems likely that the first condition of escape would be considered by the actors involved as relevant. As Rutherford (1964, p. 80) stated:

> When it comes to the teaching of science it is perfectly clear where we as science teachers, science educators, or scientists stand: *we are unalterably opposed to rote memorization of the mere facts and minutiae of science* (my italics).

In the terms of this thesis, the actors involved would probably be all opposed to Normal Science Education, whether they analyzed Dominant School Science in detail or not.

BSCS and the first condition of escape

For one curriculum project, the BSCS project, it is relatively easy to determine, at least in a global way, whether or not a prior analysis of the nature and structure of the dominant school science curriculum, in this case, the school biology curriculum, was performed.

As already noted above, prior to the BSCS project, a domain-specific analysis of the nature and structure of the dominant school *biology* curriculum was performed by Schwab (1962), as well as by Brownson and Schwab (1963), and by Hurd (1962), the latter appearing in the BSCS *Bulletin series*. Further, through many other publications, including the *BSCS Newsletter*, and at several conferences, Schwab communicated to a large audience, his analysis of the teaching of science as dogma and his idea of what should replace it, the teaching of science as enquiry. Finally, as supervisor of the "Biology Teachers Handbook" (1963), an integral part of the BSCS materials, Schwab addressed the specific needs of biology teachers themselves. Thus, he began his description of the origin of the BSCS texts with a summary of his analysis of the basic model of the conventional science textbook. He formulated as his conclusion that:

> It failed to provide a liberal, general education for all precisely because it was designed for students who would go on to college. Its design seemed to *assume* that this further education would take place for it provided not a general and well-rounded education, but prerequisite courses, "propadeutics", preliminaries. It required the college to complete its work" (ibid., p. 4).

Thus, in the case of the BSCS project, a domain-specific analysis of the nature and structure of the dominant biology curriculum was performed, and therefore, condition one was fulfilled.

BSCS and other conditions of escape

As noted above, in general terms the second condition of escape concerns the development of a vision on new science curricula, while the third condition has to do with the method one chooses in order to escape from Dominant School Science.

In many publications and at conferences, Schwab contributed greatly to the formulation of a vision of new science curricula, or in this case, of school biology curricula. During Schwab's participation in the Biological Science Curriculum Study (BSCS) project, BSCS produced from 1958 onwards *four versions* of a beginning biology course for the high school student. Three versions were aimed at the average student, the so-called Blue version (molecules to man), Yellow version (inquiry into life), and Green version (ecology); also one version for the below average student, "Biological science: patterns and processes" (ibid., pp. 54, 60, 76). While these four versions had in common the science-as-enquiry theme as propounded by Schwab (1962), each version did select a different emphasis from the structure of biology as expounded by the BSCS project.

In the *Biology Teachers Handbook,* Schwab elucidated, apart from explaining the educational philosophy of enquiry, the structure and content of biology "as that science now exits" (ibid., p. 8) in terms of seven levels of biological organization and nine biological themes (p.14). The latter included seven biological themes, as well as theme eight "Science as enquiry" and theme nine "The history of biological conceptions". Interestingly, one of his suggestions for teachers' preparation was for them to take a philosophy of science course, as "an excellent background for the Blue version" (ibid., p. 59). The *Biology Teachers Handbook* also offered *contextual* chemistry and physics, that is, chemistry and physics needed in the context of biological enquiry. Thus, in terms of Figure 3.2, Schwab was addressing here a number of 'broken' relationships, especially the relationships of school biology to past and current research (d in Figure 3.2), to history and philosophy of science and to other sciences (e, f and g in Figure 3.2). Technology (and society) was seen by the BSCS project as something distinct from science and was therefore not treated in the materials.

The BSCS texts were field tested, went through many editions, and reached in the period from 1959-1990 as many as ten million students. As we saw above, however, the results of the BSCS project, at least for the Blue version, were not found to be consistent with the educational philosophy of enquiry, either as reflected in the designed curriculum, in text or exercises, or in the interpreted curriculum by teachers (Herron 1970). In their introduction to Schwab's selected essays on *Science, Curriculum and Liberal Education*, Westbury and Wilkof (1978, p. 25) remarked that "the texts themselves were very different from what he would have wanted".

Apparently, the analysis performed by Schwab and others on the conventional biology textbook and the vision formulated on the teaching of biology as enquiry were not sufficient. These two conditions should therefore be seen as *necessary* conditions. As we saw in Figure 3.3, many other factors also appear to be relevant in order for innovation projects to succeed. Many of these factors can be summarized, I think, under the heading of a *method* of development, a method which consists of two kinds of measures:

– measures taken in accordance with the results of a domain-specific analysis;

– measures taken to safeguard the realization of the chosen curriculum vision.

In a systematic curriculum project both type of measures pertain to all curriculum levels from the visionary curriculum down to the learned curriculum, that is to all transitions of these curriculum levels. Another way to put this point is to add to the curriculum levels listed in Figure 3.3 another curriculum level, the researched curriculum. Welch (1979), for example, pointed to the lack of effective testing of the teaching materials, while Aikenhead (2000) pointed to the need for more research in combination with the development of teaching materials. Evaluative research, ideally, should pertain to all levels, from top to bottom. It should be formative and not just summative, that is, cyclic or spiral, and not linear.

In sections 3.3 and 3.4, after discussing the concept of *curriculum emphasis* as developed by Roberts (1982), I will give a further characterization of the third of escape, the *method* of development, as well as of the second condition of escape, the development of a vision. Finally, in Chapter 6, I will come back to the systemic nature of curriculum development in order to add some additional points based on my empirical findings on the Salters' Chemistry curriculum with regard to conditions supporting innovative curriculum reform.

3.2.4 A new society oriented science curriculum movement

Partly as a reaction to the sobering evaluation of the structure-of-the-disciplines curricula, there has emerged in the 1980s a new curriculum movement which attempts to reform current school science curricula in a different and possibly more radical way. Thus, it was realized that there was an urgent need to set a new, more appropriate and inclusive aim for school science, epitomized in the slogan 'Science for All', that would lead to curricula in which the *societal* and *technological* dimensions of school *science* (STS education) would find an important place. In terms of Figure 3.2, the STS movement is addressing another set of 'broken' relationships, especially the relationships of school science to technology and society (b and c in Figure 3.2).

Thus, while the movement in the 1960s tried to realize the traditional aim of understanding science by modernizing the structure and teaching of traditional, science-oriented curricula, the STS movement of the 1980s tried to articulate and operationalize a new aim leading to society-oriented curricula which would imply the development of new *content,* as well as of new forms of teaching and learning (Aikenhead, 1994).

Attempts at articulating a new vision for chemistry

Different authors have put forward different formulations for the aim of articulating a new vision for chemical education. For example, Fensham (1984, p. 209) lists a number of goals for a school chemistry curriculum which could lead to a form of chemical education effective and worthwhile for *all* students (Figure 3.4).

Figure 3.4 Some outcomes and experiences for more effective chemical education

GOALS OF CHEMISTRY FOR ALL

Every student should be able to:

- Explain a chemically-based application
- Explain how the substances of everyday live can be regarded as chemicals
- State (with relevant details) the sorts of people who find employment in the field of chemistry

Every student should have:

- Practice in the application of chemistry to real (domestic, leisure, community, etc.) problems
- Meaningful experiences of each of the major activities of chemists
- Experience, with joy and excitement, of phenomena that attract people to chemistry
- Some experience of the power of chemical knowledge

These goals do justice to the "very rich diverse conglomerate on which the word CHEMISTRY confers a common identity" (ibid., p.208, emphasis Fensham), that is, of chemistry as a field of human endeavor which includes "the processes and procedures chemists use for their purpose" (p. 208), but also includes "learning about chemical applications [and] chemicals as the substances of everyday life" (p. 211), and about "the historical development of the subject and the contributions of its historical persons" (p. 208). In terms of Figure 3.2, Fensham is addressing the relationships of school chemistry to craft, technology, and society (b and c) as well as the relationships of school chemistry to past and current research (d, e, f in Figure 3.2).

De Vos et al. (1991a, p. 8) argued for a citizen-oriented view to the school chemistry curriculum, stating that: "[t]he main aim of modern school chemistry must be to prepare students for life in a society in which chemical products and processes play an important role". One of his tentative ideas (De Vos, 1992, p. 81) was: "to situate chemical education entirely within the context of the role played by matter and energy in our society. This includes three aspects: production, use, and waste disposal thereby integrating environmental and safety problems with the subject as a whole". In his later work (De Vos et al., 2002) generalized his ideas and addressed what he called the neglected faces of chemistry: *technology, craft and magic* (cp. relationships b, c, d, e & f in Figure 3.2). Each face of chemistry incorporates a specific role which students should learn to take in De Vos's view of chemical education (see further section 6.4).

It can be inferred from the work of Fensham and De Vos, and also from the views of the large majority of researchers and developers in chemical education composing the IF and DF (Chapter 2), that these researchers all want to depart from something like the traditional, theoretical, or abstract “learning sequence for conceptual knowledge”, as Fensham (1984, p. 205) puts it (see also the work of several researchers in science education mentioned in Figure 3.3 above). That is, they all want to escape from Dominant School Chemistry as I have characterized traditional science education. Likewise, in their attempt to develop a new 16+ chemistry curriculum, the developers of Salters’ Chemistry clearly had the intention to:

> ...produce a *radical* rather than a piecemeal or cosmetic revision [of existing 16+ chemistry syllabuses characterized as academic and abstract from too early a stage (Garforth, 1983, p. 29).

However, De Vos points out that the realization of a new aim for school chemistry will require the development of new content as well as *the development of a new educational structure to organize this new content in a coherent way*. This has to be considered as the fundamental problem of chemical education. As De Vos (1992, p. 81) has put it: “the problem of an alternative structure is still on the agenda”.

Only by providing a solution for this fundamental problem will it be possible to escape from the currently dominant school chemistry curriculum, as against merely changing the traditional curriculum in a marginal or superficial way (De Vos et al., 1991, p. 8). It is to be hoped that in the end and after much developmental and research effort, this would lead to a new curriculum structure by which the new aim of school chemistry, “Chemistry for All”, would be fulfilled.

Van Aalsvoort (2000, p. 60), a Dutch researcher in chemical education, working in the cultural historical tradition, distinguishes between a gradual and a fundamental curriculum change. In her research-based attempt to develop a new elementary chemistry curriculum, Van Aalsvoort defines “a gradual change as one which leaves the core of the subject, consisting of aims, contents and teaching strategies, intact ...”,

> A fundamental change, on the other hand, consists of *an alteration of aims, contents and teaching strategies in concert,* due to their being founded in a different representation of reality (my italics).

Recently, from the 1990s onwards, there has emerged a new curriculum movement in science education which revives and articulates in new ways the emphasis on the structure and nature of the disciplines of science, by drawing in a systematic way on the important work performed in the history and philosophy of science (HPS) relevant to science education (Matthews, 1994; Millar & Osborne 1998; Duschl & Osborne, 2002). This so-called HPS education addresses the relationships of school science to the history and philosophy of science, to common sense, and to current research (cp. relationships d, e, f, and a in Figure 3.2).

Both STS education and HPS education strive after fundamental curriculum changes, which require, in terms used in this thesis, new coherent coordinated combinations of a pedagogical, philosophical, and substantive substructure that replaces the traditional combination which led to the teaching of science as dogma and to the reproduction of facts and methods. It requires a vision and a method to realize this vision, the second and third conditions for escape.

3.3 Vision, method and the concept of curriculum emphasis

In this section I will discuss the concept of *curriculum emphasis* as developed by Roberts in order to give a further characterization of the second condition of escape: the development of a vision, and the third condition of escape: the method of development. The "conceptual lens of curriculum emphasis" (Roberts (1982, p. 254), functions as a "view affording lens", as it has aptly been described, and has proved to be an important:

- Theoretical instrument to describe, analyze and explain the *vision* and structure of past and current science curricula, documents, and textbooks;

- Practical instrument to deliberate, choose, develop, sustain, and evaluate in a structured way a *vision* on new science curricula.

Thus, the concept of curriculum emphasis is an important instrument with two functions: to analyze the vision of realized science curricula, a theoretical function, and to design or develop ('synthesize') the vision of new science curricula, a practical function. A discussion of Roberts' framework will lead to important insights with regard to the second condition of escape, the development of a vision, and to the third condition of escape, the method of development. These conditions need to be fulfilled if and when trying to escape from Normal Science Education.

In the following subsections, I will therefore describe in some detail the origin, elaboration, and functions of the concept of curriculum emphasis as it has been developed by Roberts (1982; 1988; 1995; 1998).

3.3.1 The problem of curriculum diversity

Roberts, at the time a bystander in the post-Sputnik curriculum movement, reflected in later days on how much he was intrigued by the difference between the Physical Sciences Study Committee course (PSSC) and the Harvard Project Physics course. As he put it:

> The intent and overall orientation of the Harvard Project Physics course were quite different from the intent and overall orientation of the PSSC course (Roberts 1998, p. 7).

Whereas the PSSC course focused mainly on "understanding how science functions as an intellectual enterprise", the Harvard Project Physics course "presented science essentially as one of the humanities" (Roberts, 1998, p. 9). Science is taken in the latter course as one of the possible explanatory modes (Roberts, 1982, p. 248). The *Self as Explainer* curriculum emphasis, as he later called it, provides "students with grounds for understanding the process of explanation itself" (Roberts, 1988, p. 37), more than any other curriculum emphasis including the one he called *Structure of Science* of which the PSSC course was a manifestation.

Another 'different' product of this curriculum movement was the "Science – A Process Approach", developed initially for primary science education, the emphasis being on *Scientific Skill Development.* As a science student Roberts had experienced, and later as a science teacher also taught, two other types of courses prevalent in the first half of the 20th century in North-America, one with an emphasis on *Everyday Coping* and another one with an emphasis on *Correct Explanations* (ibid., pp. 8, 10).

Roberts (1988, p. 27) later defined these different curriculum products in terms of the concept of curriculum emphasis. Since his initial problem was a problem of curriculum diversity, Roberts hoped, by developing this concept of curriculum emphasis, to create some order in the emerging pluriform curriculum landscape in science education.

3.3.2 Characterizing science courses by seven curriculum emphases

In his later, more systematic studies Roberts (1982, 1988) came to distinguish, identify, and define the seven curriculum emphases in science education as depicted in Figure 3.5. These were, as he put it, developed "inductively", that is, they are based on historical research of North American science textbooks and policy statements from 1900-1980.[1]

The seven curriculum emphases "do not necessarily constitute a set of mutually exclusive categories. Rather, they capture the essence of very broadly different overall orientations which science education can assume" (Roberts, 1982, p. 246). In several places Roberts gives elaborate descriptions, as well as examples of textbooks and other teaching materials that exhibit these seven emphases (Roberts, 1982; 1983; 1988; 1998). He arrived at the insight that "[it] is impossible to teach <u>content</u> without simultaneously expressing curricular <u>intent</u>, or purpose" (Roberts 1983, p. 8; underlining his). The new curriculum emphases which emerged in the 1960s were quite "deliberately, intentionally interwoven with science subject matter" (1988, p. 10). It is important to note that this was not the case for the traditional curriculum emphases: *Solid Foundation* and *Correct Explanations*.

> However, the curriculum emphases that tend to be silent about the purpose of learning science – Solid Foundation and Correct Explanations – may not have been *deliberately* selected, but their message and socializing influence are no less powerful for that (1998, p. 10).

Roberts, therefore, briefly characterizes these curriculum emphases as *default* emphases. The number of seven curriculum emphases is not a historically, let alone theoretically, fixed number. On the contrary, new curriculum emphases can be and have been developed in the last two decades. Thus, according to Fensham (1997, 1998) curriculum emphases such as *Science for Nurturing*, *Science in Applications*, and *Science in the Making* have been emerging.

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1 Roberts refers to a number of other researchers who have "made sense of curriculum diversity in science education" (1982, p. 245). For school chemistry curricula, he refers to the work of Ogden (1975), for school biology curricula he refers to the work of Hurd (1969), and for school physics curricula he uses mainly his own studies.

Figure 3.5 Seven curriculum emphases and some examples

Curriculum emphasis	**Quotes and curriculum examples given by Roberts**	**References, Roberts**
SOLID FOUNDATION: Stresses science as cumulative knowledge	"in vogue from 1910-1950" in pre-Sputnik North-America	1998, p.7 1988, p. 38
STRUCTURE OF SCIENCE: How science functions as a discipline	PSSC, ChemStudy, BSCS late 1950s and 1960s)	1998, p.7 1988, p. 35 (1982, p. 253
SCIENCE/TECHNOLOGY DECISIONS: The role scientific knowledge plays in decisions which are socially relevant	Science in Society, ed. Lewis (1981) (largely post 1980s)	1998, p.7 1988, p. 52
SCIENTIFIC SKILL DEVELOPMENT: The 'science as process' approach	Science – A Process Approach (AAAS)	1978, p.5 1988, p. 37
CORRECT EXPLANATIONS: Science as reliable, valid knowledge	"very noticeable" in pre-Sputnik North America	1998, p.10
PERSONAL EXPLANATION: Understanding one's own way of explaining events in terms of personal and cultural (including scientific) influences	Harvard Project Physics (Watson, Holton) Harvard Case Histories (Conant et al., 1948) Patterns of Discovery (Connelly et al., 1972)	1998, p. 9 1988, p. 52 1982, p. 248
EVERYDAY APPLICATIONS: Using science to understand both technology and everyday occurrences	prevalent in North-America (1910-1950) "learn how to apply"	1998, p. 8 1988, p.34 1982, p. 244

3.3.3 Theoretical functions of the concept of curriculum emphasis

The framework around the concept of curriculum emphasis should be seen as:

> ...an analytical framework for understanding what is involved for policy makers, and for science teachers, when they shape answers to the question: What counts as science education? (Roberts, 1988, p. 27).

It is an analytical framework to make sense of past or present curriculum diversity and of the development of future curricula. The concept of a curriculum emphasis is defined as:

> ...a coherent set of messages to the student about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws and theories of the subject matter itself – objectives which provide an answer to the student question: "Why am I learning this?" Roberts (1982, p. 245).

The meaning of a curriculum emphasis, taken as a “coherent set of messages”, can be ‘unpacked’ by using the idea of the ‘common places’ of the curriculum (Roberts, 1988, p. 45). There are four common places (Figure 3.6) which constitute the elements of meaning of any curriculum proposal: (i) the subject matter; (ii) the learner; (iii) the teacher; and (iv) the society in which the teaching occurs. Furthermore, these four common places have to form, as Schwab (1962, pp. 31 – 41) repeatedly stressed, a coherent and *co-ordinate* set of messages.[2]

Each curriculum emphasis, taken as an inevitable combination of subject matter and an objective going beyond content, can be realized in the span of one teaching unit, taking “five to six weeks of instruction” (Roberts, 1982, p. 250), that is, about 12 lessons. In this period the teacher can communicate the new emphasis, perform his or her new role, and the student can learn the new emphasis of the unit. Roberts gives examples of units conceived, developed, and taught in accordance with the particular emphasis in his discussion on the Ontario and Alberta curricula. Furthermore, he stresses the importance of:

> A research summary/analysis about a single emphasis, in terms of who can master it, how well, at what ages, what the unintended consequences are, etc. (ibid., p. 255).

Thus, Roberts also requires *evidence* for the realization of a new emphasis. The chosen vision or innovation should be shown to work, should be feasible.

The realization of a new emphasis in the span of one unit has an important corollary, namely, that it is possible to deal in a science course of one or more years with *more than one* emphasis. Therefore, one curriculum emphasis does not have to dominate a whole science course in order to come across for students. This is a powerful argument, according to Roberts, for those curriculum proposals which consist of a balance of different emphases. Since science has several facets, students of different age and ability should meet more than one of these facets as a preparation for their future lives. Each emphasis is in principle “a legitimate candidate for choice” (Roberts, 1988, p. 38).

In sum, a curriculum emphasis in science education consists of a coordinate set of messages about science, the learner, the teacher, and society. It can be empirically shown to be feasible, that is, teachable and learnable, in the span of one unit. One curriculum emphasis is neither more correct nor truer than another, and shouldn’t therefore dominate a science curriculum for secondary education. Its legitimacy should be defended with regard to specific students and circumstances.

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2 Similarly, Orpwood and Roberts (1978, p. 5) state that “an emphasis contains a selected set of messages (to the student) about science, about himself, about society, or about the relations among them”.

Figure 3.6: Seven curriculum emphases for science education in terms of four commonplaces (From: Roberts, 1988, p. 45)

Curriculum emphasis	View of Science	View of the learner	View of the teacher	View of Society
Everyday Coping	A meaning system necessary for understanding and therefore controlling everyday objects and events.	Needs to master the best explanations available for comfortable, competent explanation of natural events, and control of mechanical objects and personal affairs.	Someone who regularly explains natural and man made objects and events by appropriate scientific principles.	Autonomous, knowledgeable individuals who can do mechanical things well, who are entrepreneurial, and who look after themselves, are highly valued members of the social order.
Structure of Science	A conceptual system for explaining naturally occurring objects and events, which is cumulative and self-correcting.	One who needs an accurate understanding of how this powerful conceptual system works.	Comfortably analyzes the subject matter as a conceptual system, understands it as such, and sees the viewpoint as important.	Society needs elite, philosophically informed scientists who really understand how that conceptual system works.
Science/ Technology/ Decisions	An expression of the wish to control the environment and ourselves, intimately related to technology and increasingly related to very significant societal issues.	Needs to become an intelligent, willing decision maker, who understands the scientific basis for technology, and the practical basis for defensible decisions.	One who develops both knowledge of and commitment to the complex interrelationships among science, technology, and decisions.	Society needs to keep from destroying itself by developing in the general public (and the scientists as well) a sophisticated, operational view of the way decisions are made about science-based societal problems.
Scientific Skill Development	Consists of the outcome of correct usage of certain physical end conceptual processes.	An increasingly competent performer with the processes.	One who encourages learners to practice at the processes in many different contexts of science subject matter.	Society needs people who approach problems with a successful arsenal of scientific tool skills.
Correct Explanations	The best meaning system ever developed for getting at the truth about natural objects and events.	Someone whose preconceptions need to be replaced and corrected.	One responsible for identifying and correcting the errors in student thinking.	Society needs true believers in the meaning system most appropriate for natural objects and events.
Self as Explaner	A conceptual system whose development is influenced by the ideas of the times, the conceptual principles used, and the personal intent to explain.	One who needs the intellectual freedom gained by knowing as many of the influences on scientific thought as possible.	Someone deeply committed to the concept of liberal education exposing the grounds of what we know.	Society needs members who have a liberal education ñ that is, who know where knowledge comes from.
Solid Foundation	A vast and complex meaning system which takes many years to master.	An individual who wants and needs the whole of a science, eventually.	One who is responsible to winnow out the most capable potential scientists.	Society needs scientists.

3.3.4 Practical functions of the concept of curriculum emphasis

In the late1970s Orpwood and Roberts (1978; 1979; 1980), applied for the first time the science curriculum framework centered around the concept of curriculum emphases. From the beginning they stressed the practical functions of the concept of curriculum emphasis and illustrated the heuristic potential of their view-affording lens "for the practical science education activities of curriculum policy formulation, materials development, and curriculum implementation in the classroom" (Roberts 1982, p. 249).

Using the 'lens' to analyze a vision

Orpwood and Roberts (1978) began to use the concept of curriculum emphasis for an analysis, clarification, and discussion of proposed curriculum guidelines for science education in the state of Ontario, Canada, for the Intermediate Division (grades 7-10; ages 12-16). The first thing they did was to group "the varied, though clearly not exhaustive list of Aims statements" (ibid., p. 5) in three distinct clusters:

- A *subject-centered* emphasis, characterized as: "science as a means for students to reflect on the nature of the discipline" (ibid., p. 5).
- A *learner-centered* emphasis, characterized as "the development of scientific skills in the learner" (p. 5).
- A *society-centered* emphasis, characterized as: "aims having their focus beyond school and the discipline toward the role of science and the science student in societal contexts" (p. 5).

Categorizing a multitude of aims in terms of three clusters or emphases, makes it possible for the policy and development committee:

> ...to discuss some of what is otherwise *implicit* in a curriculum, and thus to plan for one set of messages (a desired set) rather than another set to be incorporated into a science program (p. 6).

To put it in the terms of this thesis: making things explicit with regard to the envisioned curriculum is a necessary condition for escape.

Roberts and Orpwood participated in various forms of both research and development work, as "principal investigators", in which the analytical use of the conceptual lens of curriculum emphasis occupied a central place. At the policy level, or visionary curriculum level, they contributed an article to the provincial guidelines called "Relating Science Topics to Alternative Sets of Objectives" (Orpwood & Roberts, 1978, p. 5). They participated in the regular meetings of the planning committee for curriculum development and when clarification was needed, in a large representative group meeting twice a year. Finally, they recorded all policy deliberations, for subsequent transcription and analysis (Roberts, 1982, p. 250), a rare example of collecting research data on the policy or visionary curriculum level.

The following use of the concept of curriculum emphasis concerns the designed curriculum level. Orpwood and Roberts developed, in cooperation with science teachers, a grade 7/8 unit which focused on the topic *Properties of Matter* (1979, p. 4). They did this "in three alternative versions together with a commentary about alternative versions" (Orpwood & Roberts, 1979).

> When produced in trial form for teachers to implement in the classroom, the materials were even color coded: blue for Structure of Science, red for Scientific Skill Development, and green for Science and Society (Roberts 1982, p. 252).

The popularity of this "multiple-version manual" as well as the number of requests for professional development sessions in which different curriculum emphases are explained, articulated, and applied, indicates "that the use of the concept as an active, systematic approach to materials development has been very successful indeed" (Roberts 1982, p. 252).

Using the 'lens' to articulate a vision

Another function of the conceptual 'lens' of curriculum emphases in the area of policy, is discussed in Roberts (1995) where he describes how, in the period from 1986-1992, a curriculum committee devised a threefold strategy *based on* the concept of curriculum emphasis. The policy formulation concerned a revision of a science curriculum policy for junior high school (grades 7-9; ages 12-15) in the province of Alberta, Canada.

First of all, looking through the conceptual lens of curriculum emphasis, the committee saw "science subject matter as present throughout the program" (ibid, p. 499). The use of the conceptual lens led the committee to the insight that the required subject matter could be incorporated in the program while using *any* of the seven curriculum emphases, whether they were more traditional ones or more alternative ones. As a result, the two most traditional or 'default' emphases, *Correct Explanations* and *Solid Foundations* (both of which implicitly communicate to students a study of subject matter for its own sake) were discarded. We could say that, by performing the analysis afforded by the conceptual 'lens' of curriculum emphases, the committee broke away from, and did not import, the two most traditional emphases on school science. In other words, they were making an attempt to escape from Normal Science Education.

Secondly, the remaining five curriculum emphasis were amalgamated to form three program emphases, called "Learning Contexts" by the committee (Figure 3.7).

Figure 3.7 Amalgamation of curriculum emphases into three learning contexts

Curriculum emphases	**Learning Contexts**
Structure of Science, Scientific Skills Development, and Personal Explanation	Nature of Science
Everyday Applications	Science and Technology
Science/Technology/Decisions	Science, Technology and Society

Thirdly, these three *Learning Contexts* "were to be blended with different sections of content to achieve the desired balance of objectives" (ibid. p. 499). In other words, appropriate topics from the mandatory list consisting of concepts, attitudes, and skills were blended with one of the three selected learning contexts. This, according to Roberts

(p. 499), was the boldest move of all, that is, "to attach a learning context to each subject matter unit, to insist that the units would be taught that way" (p. 499).[3] Thus, the use of the conceptual 'lens' of curriculum emphases enabled the curriculum committee to formulate a coherent vision.

Using the 'lens' to safeguard consistency of vision in the development process

After the selection of a particular set of curriculum emphases follows the process of development of materials in which the selected curriculum emphases are articulated and operationalized. Two other curriculum elements should be addressed in this process, namely, science content and teaching strategy (Figure 3.8). Orpwood and Roberts point out that:

> It is reasonable to expect these *differing* emphases to be represented in the classroom in the form of *differing* teaching strategies (Roberts & Orpwood, 1978, p. 6; my italics).

Figure 3.8 Relationship between science content, curriculum emphasis, and teaching approach (Orpwood & Roberts, 1978, p. 4)

Science content (fixed)	+	Curriculum emphasis (selected)	→	Teaching strategy (selected)

Although Figure 3.8 reads, in particular for teachers, 'logically' from left to right, as Orpwood and Roberts put it, they do stress at the same time that "the order used in planning a curriculum and designing units, is a matter for individual choice" (1978, p. 7). Whatever order is chosen, it is especially important to monitor, during the development of materials, the "*logical consistency* among science content, objectives, and teaching approach at every stage of the unit" (1979, p. 6, my italics). And they elaborate on this point, saying:

> It means, in practice, that one has to "revisit" each of the three columns frequently to make additional "fine tuning" until the required consistency is there" (ibid., 1979, p. 6).

This was the case in the materials development of the Alberta project:

> The textbooks, and the curriculum guides, take the concept of curriculum emphases seriously, so that each of the subject matter units *clearly and consistently* deploys the necessary blend of science topics and the Learning Context (Roberts, 1995, p. 503; my italics).

Thus, at the visionary or policy level, the concept of curriculum emphasis is a good starting point in order to make sense of, and then cluster or reduce, the multitude of objectives in a *given* policy document (top-down approach). On the other hand, the actors involved in a bottom-up developmental project should be able to deliberate on a desired

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3 This raises the question, to what extent developers and teachers were able *to adhere consistently* to the design criteria following from the specific choice of curriculum emphases by the curriculum committee. In Chapters 4 & 5, I will try to answer in some detail a similar question for the Salters' Chemistry curriculum. It would be very interesting to perform a 'consistency' analysis on the materials produced by the group of authors (Durward et al., 1989) for which Roberts acted as program consultant.

set of curriculum emphases and decide accordingly, which set to develop further.[4] Subsequently, either approach goes on to model or match, in a tentative and empirical way, the selected emphases with appropriate subject matter and with a suitable teaching strategy by 'fine tuning' in a process of 'dialectic recursive interaction'.

Roberts and Orpwood further point out that designing units for students also requires developers to address a fourth curriculum element, namely, the "evaluation of student achievement" (1979, p. 5), or the assessment of student achievement (Figure 3.9).

Figure 3.9: Four curriculum elements (adapted from Orpwood & Roberts, 1979, p. 5)

Science Content	Objectives	Teaching Approach	Evaluation (Assessment)

For the relationship between these four curriculum elements they stress that:

> These four elements are like the pieces of a jigsaw puzzle that require careful fitting together. As with the jigsaw, the selection of each piece has consequences for the selection of subsequent places (ibid., p. 5).[5]

As Roberts (1995, p. 497) puts it, such a "planning procedure also facilitates writing legitimate test items to assess students understanding". The developmental strategy should result in students exhibiting a behavior that can constitute reasonable evidence for the achievement of the objectives. The coherence and flow of the selected emphasis are matters of concern just "as much as the coherence and flow of the subject matter itself" (Roberts 1982, p. 251).

Upholding the 'logical consistency' between the four curriculum elements, by way of 'fine tuning' in a process of 'revisiting' these curriculum elements, can be seen as a general mechanism, part of new model of curriculum development which Roberts (1999, p. 125), following Schwab (1974, 1978), has described as follows:

> It has to do with the *dialectic, recursive interaction* between Purpose and Policy (ends) and Programs and Practice (means). That is, seeing the former as settled, without considering the implications of the latter, is simply not going to work, in Schwab's view.

As we will discuss in section 3.4, "dialectic, recursive interaction" can be seen as an important part of the process of 'developmental research', as practiced to varying degrees by the developers and researchers at the Center for Science and Mathematics Education, Utrecht University, The Netherlands (see further in Chapter 6).

Thus, it is very important to have a systematic method for safeguarding the consistency of an adopted vision while developing teaching materials and testing them in the classroom. The gathering of evaluation data at the different curriculum levels is essential for making appropriate curriculum decisions about clarity and consistency of

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4 For example, in Westbroek et al. (2000) a choice is made to elaborate the three curriculum orientations as discussed by Van Berkel (2000).

5 The metaphor of the jigsaw is also applied by Westbroek et al. (2001) to describe the process of fitting together the substantive, philosophical, and pedagogical substructures of a curriculum, in a coordinated way, *within* a particular chosen curriculum emphasis, as well as across diverse curriculum levels, thus elaborating a point made by Van Berkel (2000).

vision, on the one hand, and feasibility of the teaching, learning, and assessment process, on the other. Data should be collected at the policy or visionary curriculum level, at the designed, taught, and learned levels. Another way to put it is that developmental research on science curricula should be not only classroom based, but also design-room based and vision-room based.

In Chapter 1 we saw that the researchers of the Dutch MAVO chemistry project concluded, on the basis of a consistency analysis, that the developers of the project did not achieve the "Chemistry for the Citizen" aim which they set out to achieve. In Chapters 4 and 5, I perform a consistency analysis on the Salters' Chemistry curriculum in order to see to what extent the developers in England were able to realize their vision of a societal chemistry course.

Using the 'lens' for purposes of curriculum implementation

Roberts and his colleagues in several publications (e.g. Orpwood & Roberts, 1978, 1979; Roberts & Chastko, 1990; Roberts, 1988) examine different orderings of the curriculum elements discussed above, in line with their point about the ordering being a matter of individual choice. The ordering chosen is determined by the curriculum level addressed e.g. the visionary, designed, written, or taught curriculum (see par. 1.3.1, Goodlad). In other words the purpose of the curriculum work performed, e.g. content analysis of existing textbooks (written curriculum) or the design of new curriculum units (designed curriculum), determines the chosen order.

Content analysis of textbooks for in-service teachers

When performing content analysis of textbooks at the written or formal curriculum level, it is helpful for teachers to look at the teaching strategy as exemplified by the organization of the textbook, and then perform an analysis by following Figure 3.8 in reverse order (or backwards).

Such a 'reversed' analysis will reveal the selected curriculum emphasis which is often presented, at least with default emphases, in an implicit way and the science content selected to match these curriculum emphases (Orpwood & Roberts, 1980, p.38). The latter application of the concept of curriculum emphasis has led to "a rather popular scheme for practitioner use in analyzing textbooks to determine curriculum emphasis" (Roberts, 1982, p. 258). Teachers familiar with the conceptual lens of curriculum emphasis can also use it to guide their efforts to develop additional materials they want to use with their students in order to teach a selected curriculum emphasis (more) adequately.

Content analysis of textbooks for pre-service teachers

It is interesting to mention in this regard the "Science Teacher Thinking Framework" (STTF) as explored in Roberts and Chastko (1990, p. 200). The STTF depicted in Figure 3.10 contains similar curriculum elements to those mentioned before. That is, the heading *Objectives* of the third column of Figure 3.10 can be equated with the heading *Curriculum emphasis* of the second column in Figure 3.8, and the heading *Student Responses* of the fourth column in Figure 3.10 can be equated with the heading *Assessment* of the fourth column in Figure 3.9).

Figure 3.10: A Science Teacher Thinking Framework

Subject matter: +	**Teaching strategy:** ➤	**Objectives:** ⟷	**Student responses:**
What science is being taught?	What do I do in the classroom?	What is supposed to happen to students?	How do I know what is happening to students?

The authors discuss this framework in the context of a teacher training course they have developed, with the aim to make teachers aware of different emphases in curriculum materials or science textbooks. Teachers participating in this course should acquire, what they call following Schwab, a "view-affording lens" in the form of the concept of curriculum emphasis.[6] Thus, here is put into practice what is proposed by Roberts (1988, p. 51), namely:

> At the very least, teachers deserve to be taught that different curriculum emphases are possible, and that a particular view of what counts as science education (whoever holds or presents it) has been selected (by the person, albeit a professor of science education) from an array of alternatives.

3.4 Discussion

In this last section we will discuss some of the problems with the implementation of new curriculum emphases (3.4.1), the relationship between the concept *curriculum emphasis* and the concept *Normal Science Education* (3.4.2), and come back to the three conditions of escape in relation to the concept *'developmental research'* (3.4.3).

3.4.1 Problems with implementation of new curriculum emphases

For teachers not directly involved as co-developers in the development of the new curriculum built around a new set of emphases, a certain "resistance" (Roberts, 1995, p. 501) to the new emphases can be expected – at least, more than from trial teachers involved in some way in the process. For science curricula, introducing such non-academic emphases, such as *Personal Explanation, Science/Technology/Decisions*, and *Everyday Applications,* the typical comment of teachers and/or administrators is, "This stuff isn't science, it's social studies!". Depending on the emphasis, it is seen as philosophy, technology, or applied science (1982, p. 252; 1995, p. 502), not a proper science. Thus, teachers show an "intense, almost fierce affiliation to an academic direction which school science teaching tends to show" (Roberts, 1988, p. 49).

6 This could be seen an example of applying Goodlad's curriculum levels (see Ch.1), usually applied to student (training) courses, to teacher training courses. Thus the concept of curriculum emphasis, as developed by Roberts, is taught to teachers, and the research performed aims to find out what is learned by teachers about this concept.

In the broadest sense this academic tradition is composed of four curriculum emphases: Solid Foundation, Correct Explanations, Structure of Science, and Scientific Skill Development. The first two of these traditional emphases seem to have the strongest hold on teachers and other practitioners, and are aptly characterized by Roberts as “default emphases”. That is, teachers do not explicitly state their goal, but implicitly seem to say, in the case of Solid Foundation: “Learn this stuff ... to get ready for the stuff you are going to learn next year” (Roberts, 1988, p. 38) or “Master now, question later” (Roberts, 1982, p. 248). Or, in the case of the curriculum emphasis Correct Explanations, the message is simply “Learn it because it is correct” (ibid., p. 37). The other two academically oriented emphases became more prominent in the post-Sputnik period and can be seen as modernized versions of the first two. In this they can be presented in revolutionary or radical forms, approaching Personal Explanation, or in more traditional forms, approaching the default emphases Solid Foundation and Correct Explanations, for example in the hands of academically oriented teachers.

As long as teachers cannot see the legitimacy of teaching science units with curriculum emphases which depart from the academic emphases they have been used to in their own schooling and teaching, they will feel that the new materials take “time away from the ‘real science’” (Roberts, 1995, p. 502). Many of these teachers, Roberts explains, grew up on structure-of-the-discipline courses (BSCS, ChemStudy, PSSC). They studied these and now teach them (Roberts, 1982, p. 252), so the possible legitimacy of other curriculum emphases is difficult for them to comprehend. These teachers say, for example, that the structure of science emphasis is the proper one, or even the ‘correct’ one. One of the most important points the conceptual lens of curriculum emphases ought to bring home to practitioners is that the notion of correct or true does not really apply to curricular arguments. As Roberts and Orpwood have argued from the beginning:

> An emphasis is judged in terms of it defensibility for particular students under particular circumstances. One emphasis is not more correct than another (1988, p. 38).

Effectiveness is part of that defensibility, as is legitimacy, but correctness is not. Looking at science curriculum reform from the standpoint of the theory of curriculum emphasis, resistance from teachers to radical reform can almost be predicted. It is therefore likely that by providing “specifically designed” (Roberts 1995, p. 502) textbooks and other support materials, and (in-service) teacher training, the degree of resistance can be substantially reduced, as Roberts argues and showed for the case of the teachers in Alberta (ibid., p. 502).

The point about the defensibility of the new materials is, that its new curriculum emphasis can be defended as meaningful and worthwhile for a particular group of students, say of lower secondary mixed ability, to learn these materials.

3.4.2 Normal Science Education and the concept of curriculum emphasis

Roberts distinguishes seven curriculum emphases which he initially subsumes under three main curriculum orientations: subject-centered, learner-centered, and society-centered (Roberts, 1978). In another practical case of curriculum development, these seven emphases were clustered in three learning contexts: one combining a learner- and subject-centered orientation and two other society-centered orientations on science (Roberts, 1995, p. 499)

From my analysis of the IF responses there emerged three main curriculum orientations, which I called Normal Science Education; Science, Technology and Society; and History and Philosophy of Science. These curriculum orientations seem to be similar to those used by Roberts and similar also to other tripartite divisions made by several other authors such as Goodson (1987), De Boer (1991), and Matthews (1994).

Two of Roberts' curriculum emphases, *Solid Foundations* and *Correct Explanations*, are characterized by him as default emphases, because they are used as a means to communicate the message of science curricula in a silent and implicit way. The curriculum orientation labeled Normal Science Education can, I think, be taken as an amalgam of these two default emphases. Apart from its implicit function, I have characterized Normal Science Education with regard to the dominant school chemistry curriculum as having a rigid and isolated structure (section 2.3.).

Because of these properties, the replacement or even the reduction of this dominant curriculum orientation is bound to raise resistance or difficulties. This point is probably brought out more by the analysis in terms of the concept of Normal Science Education, since it stresses dominance, rigidity, and isolation of the curriculum, while Roberts concept of curriculum emphasis focuses on curriculum diversity and change.

The specific unpacking of the structure of the dominant school chemistry curriculum (based on the research reported in Chapter 2) has led to a detailed characterization in terms of a substantive structure, labeled corpuscular theory, a philosophical structure, labeled educational positivism, and a pedagogical structure, involving initiatory and preparatory training of future chemists. My characterization is specific for the dominant school chemistry curriculum, and because of its rigidity and isolation, foresees the resistance which will manifest itself in case of reform, and to a varying extent at all curriculum levels involved. In brief, my analysis in terms of the concept of Normal Chemistry Education, gives a specific edge to Roberts' valuable general analysis in terms of default emphases. Any fundamental reform can, of course, expect resistance from those actors, or stakeholders (Fensham, 1998), who support the traditional view of science education. In terms of the concept of Normal Chemistry Education, we can expect more specifically, for any attempt to escape from Dominant School Chemistry, a rigid adherence to the current combination of the pedagogical, philosophical, and substantive substructures of school chemistry.

As for the substantive structure, it can be expected that only marginal revisions will be allowed, that is, that some topics or concepts will be deleted (or added!) without changing the core of the traditional, corpuscular oriented content. A more radical change of content would be required, if and when a new curriculum emphasis would be taken up seriously. It would mean that a new substantive structure would have to be coordinated with a new pedagogical structure and new philosophical structure.

The recent reform of school chemistry in lower secondary education in the Netherlands ("Basisvorming") though fundamental in intent, turned out to be rather superficial in practice. with regard to content and teaching approach still largely of a traditional nature. As such, it is a good example of the mechanism of resisting fundamental change (Van Aalsvoort, 2000).

A radical reform of the current philosophical structure (educational positivism) would have to replace the ruling textbook image of science, which is still deeply ingrained in current textbooks, in the practice of teaching, and to a large extent also in the practice of teacher training, with a more philosophically valid position (Hodson, 1988). Many aspects of scientific research receive a simplified treatment in science textbooks. For example, the scientific method is reduced to a number of steps (Schwab, 1964), and the process of measurement is not dealt with explicitly but by implicit definitions, hidden from students (Kuhn, 1963).

It is likely that teachers, who are not familiar with a more valid philosophy of the science underlying scientific research, will fall back on some version of the textbook image of science, especially when the 'new' textbooks are not coherent in the philosophical message communicated.

Some of the latest curriculum reforms of school science address in their pedagogical structures a number of often fundamentally new aims or attainment targets, without as a rule being very specific about the teaching strategies which are needed to realize these new aims. This calls for developmental research projects in which teaching approaches need to be developed and adapted to any new aim or curriculum emphasis. Teachers, as well as students, need at least some heuristic which will lead them to the newly set aims (Janssen, 2004). Failing such an heuristic, whether for a *Science Technology and Society* oriented curriculum or for a *History and Philosophy of Science* oriented curriculum, teachers and students will, as before, fall back on traditional strategies such as transmission and reproduction.

3.4.3 Conditions of escape and the concept of developmental research

In attempts to develop a fundamentally new curriculum emphasis – matching in a coordinated and coherent way a new curriculum structure to a new curriculum aim – it seems be necessary to accompany the fundamental curriculum reform with systematic *developmental research*, succinctly described by Lijnse (1995, p. 192) as follows:

> The design of such teaching is therefore necessarily an empirical process of closely interconnected research and development, that we call "developmental research". It concerns a cyclical process of theoretical reflection, conceptual analysis, small-scale curriculum development, and classroom research of the interaction of teaching-learning processes.

Given the tentative nature of such a project, it is mandatory that, at each level of the curriculum project, sufficient data are collected in order to test the validity of the new hypothetical curriculum vision and to arrange for the necessary revision or feedback. This is like "the dialectic, recursive interaction between Purpose and Policy (ends) and Programs and Practice (means)", the process discussed by Schwab and Roberts earlier.

This labor-intensive and time-consuming developmental research has been used, up to now with reasonable success, mostly in the development and operationalization of individual units or topics (Vollebregt, 1998; Janssen, 1999, Kortland, 2001; Van Rens, 2005; Westbroek, 2005). The need to apply developmental research (Lijnse, 1995) to large-scale curriculum projects, though, is being gradually realized (for example, see Aikenhead, 1997).

Thus, the difficulty to escape consists, after knowing where to escape from, in the need to develop a coherent, new vision. This is a complex task requiring an innovative strategy preferably combined with painstaking developmental research at a number of curriculum levels addressing the coordination of the three substructures. Feedback of this developmental research is needed both to articulate and revise the tentative new vision and to identify and hopefully overcome the pitfalls and resistance met during the fundamental reform of the traditional curriculum structure of school chemistry (See Figure 3.11).

Figure 3.11 Three conditions of escape

Condition one: *In order to escape, we have to know what to escape from.*

- Perform a domain-specific analysis of the structure of the currently dominant school chemistry curriculum, using the curriculum framework developed here.

Condition two: *In order to escape, we have to know what to escape to.*

- Aim towards a coordinated replacement of the currently rigid combination of a substantive, philosophical, and pedagogical structure of school chemistry.
- Develop and legitimize a new coherent vision on the structure of a school chemistry curriculum, that is, a new curriculum emphasis for school chemistry, taken here as a new combination of a substantive, philosophical, and pedagogical structure.

Condition three: *In order to escape, we have to know how to escape.*

- Use a systematic method to articulate, operationalize, and implement the new, conjectural vision, which should operate in the following ways:
- Collect evaluation data at all curriculum levels to safeguard the adopted vision.
- Be aware of, anticipate, and avoid, or at least deal in time, with any difficulties related to the dominant school chemistry curriculum at all curriculum levels.
- Check the newly chosen curriculum emphasis for consistency at all curriculum levels: from the visionary, designed curriculum up to the taught and experienced curriculum level.

In the next two Chapters we will see how the Salters' Chemistry Project fares in the complex curriculum areas of development, research, and implementation. The detailed evaluative research reported will enlighten us in important ways about how the three conditions of escape can be fulfilled, that is, how to articulate a new vision while preventing the importation of the old one, and to plan, realize, and test the new vision by developmental research.