4 Salters' Chemistry: A curriculum analysis of its development process

" ... a window of opportunity ..."
Francesca Garforth

I start this chapter by describing the aims, rationale and method chosen for the evaluative research into the Salters' Chemistry curriculum, a Science, Technology and Society (STS) curriculum which made a serious attempt, by trying to develop a relevant 'Chemistry for All' course, *to escape from* Normal Chemistry Education (NCE) as embodied in England in a core chemistry syllabus (section 4.1).

The developmental process of the Salters' Chemistry project is analyzed in terms of the curriculum theoretical framework presented in section 1.3, that is, in terms of Schwab's substructures pertaining to each curriculum level (Goodlad) of school chemistry, Roberts' concept of curriculum emphasis, and the Kuhnian concept of normal chemistry education.

In order to determine whether, and to what extent, the developers succeeded in their endeavors, I first describe the problem situation in secondary chemical education in England in the 1970s as perceived and diagnosed by the developers, in particular by the project manager Francesca Garforth (4.2). Out of this evolved their vision of an alternative provision of chemistry for the secondary school level, to be called here the *visionary* curriculum (section 4.3). The promising results of designing relevant chemistry units in a first workshop, that is, of the *designed* curriculum, led to the decision of the developers to embark on a *full-scale* trial: the subsequent design of a one-year transitional course in chemistry for 13-14 year olds (section 4.4), followed by the development of a two year exam course in chemistry for 14-16 year olds (section 4.5).

The final revision of the *written* curriculum led to the formal acceptance of the GCSE Salters' Chemistry course for 13-16 year olds by an examination board, that is, the *formal* curriculum (section 4.6).

In sections 4.3-4.6, I compare, in terms of my theoretical curriculum framework, the successive curriculum phases of the Salters' Chemistry project: "Vision", "First articulation", "Year Three", "GCSE draft", and "GCSE revised" with the traditional 'academic' provision of school chemistry for 13-16 year olds as it existed in England at the time. Finally, I will discuss the results of these comparisons, the process of transformation of one curriculum level to another, and the *degree of escape* of the realized Salters' Chemistry course from NCE (section 4.7).

In the next, complementary chapter *Analysis of "Metals", a Chemical Unit of the Salters' Science Curriculum*, I perform a similar curriculum analysis on one of the chemical units of the Salters' Science curriculum, *Metals*, as designed by the developers. Here the analysis is extended to the curriculum unit as interpreted and taught by a teacher, and experienced and learned by students in the classroom.

4.1 Aims, rationale, and methods of research

First described here are the aims of my evaluative research on the Salters' Chemistry curriculum (4.1.1), followed by the rationale for choosing Salters' Chemistry as an object of study (4.2.2), and a discussion of the evaluative method I have used in this chapter and the next (4.3.3).

4.1.1 Aims of research

The aims of my evaluative research into the Salters' Chemistry[1] curriculum are to:

- analyze the Salters' Chemistry curriculum in terms of my curriculum theoretical framework in order to determine in what respects its curriculum structure *differs* from the traditional structure of dominant school chemistry;
- analyze the process of transformation of one curriculum level to another, and ascertain the degree of escape of the Salters' Chemistry course from dominant school chemistry, taken as a form of Normal Chemistry Education;
- explain these differences, mechanisms of transformation, and the degree of escape in terms of the concept of Normal Chemistry Education;
- assess the usefulness of my curriculum theoretical framework for analyzing both traditional and innovative school chemistry curricula.

4.1.2 Rationale for choosing Salters' Chemistry as an object of study

In Chapter 2 I have described the rigid structure of the currently dominant school chemistry curriculum, and given a functional explanation of this international curriculum phenomenon in terms of the concept of Normal Chemistry Education (NCE). This leads us to the question: to what extent it is possible, if so desired, to *escape* from dominant school chemistry or NCE?

The Salters' Chemistry course, an STS school chemistry curriculum for 13-16 year olds, seemed to observers, and was claimed as such by the developers, to be a *radical* departure from traditional school chemistry as it existed in England in the 1980s. Thus, a number of well known researchers and developers of chemical education present at the 11th International Conference on Chemical Education (ICCE), having heard several presentations on the rationale, characteristics, and effectiveness of the Salters' Science approach, seemed to think that the Salters' Chemistry course was a revolutionary alternative to traditional school chemistry (Kempa & Waddington, 1992). Put in terms used in this thesis, Salters' Chemistry seemed to these observers to be a bold attempt to

1 The Salters' Institute of Industrial Chemistry offered, from 1982 on "considerable financial help and encouragement" (The Salters' Chemistry Course, An Overall Guide for Teachers, 1988, p. 81), while large industrial organizations provided the rest of the funding. The projects developed and managed by the University of York Science Education Group (UYSEG) have been called "Salters' Projects", e.g. Salters' Chemistry, Salters' Advanced Chemistry, and Salters' Science.

escape from dominant school chemistry, both from traditional school chemistry *teaching* and from traditional school chemistry *content*. These perceptions were shared, as we saw in Chapter 2, by about half the members of the International Forum (which included some of these observers) and by a number of members of the Dutch Forum.

A first, global characterization of the Salters' Chemistry course can be given in terms of Roberts' curriculum emphases, namely, as a relevant school chemistry course which combines an emphasis on *Everyday Applications* by using science to understand both technology and everyday occurrences, and a curriculum emphasis on *Science, Technology, Decisions* by adducing the role scientific knowledge plays in decisions that are socially relevant (see section 3.3, Figure 3.6). The Salters' Chemistry course can be given a further categorization as a "Science through STS" curriculum (Aikenhead, 1994, p. 55), a categorization which taken over by the Salters' development team, albeit with some reservations (Campbell et al.,1994). In line with this, one could categorize the Salters' Chemistry course as a C*hemistry through CTS* curriculum (CTS), that is, as a school chemistry curriculum which attempts to make school chemistry relevant for all students by connecting chemistry as a science to the technological and societal contexts of chemistry present in students' daily lives (see further section 5.1.4).

Aikenhead (1994) has formulated his categorization of STS courses in terms of STS content and "Pure Science" content. In the Salters' Chemistry course then, STS, or rather CTS content set in a CTS context, is meant to serve as an organizer both for the Pure Chemistry *content* used or needed to make sense of the CTS context and for the *sequence* of chemical concepts deployed in teaching. That is, the CTS content set in a CTS context is seen as a *central* component of the school chemistry course and is not merely added on to a traditional theory-driven, pure chemistry course (Holman, 1987; Fensham, 1992).

CTS curricula such as Salters' Chemistry are to be seen as largely different from the curriculum products of the 1960s and 1970s which attempted to modernize science curricula in terms of general theoretical concepts and by emphasizing scientific inquiry and reasoning processes while, predominantly, aiming at recruiting future scientists (section 3.2). Such science-oriented curricula as part of their pedagogical structure largely retained the traditional aim of preparing students for the future study of science, by offering an upgraded version of the traditional substantive and philosophical structures of science curricula. In reaction to the sobering analysis and critical evaluation of this 'wave' of science-oriented curriculum projects, STS curricula of the 1980s generally attempted to effect different and more radical changes in traditional school science. Formulated in terms of Schwab's curriculum categories, an STS or CTS curriculum, here Salters' Chemistry, attempts to change in a coordinated way the:

- Pedagogical structure: both through its aim, *Science for All*, and through its context-led teaching approach from which (the sequence of) concepts emerge;
- Philosophical structure: by emphasizing everyday life and the societal and technological contexts of chemistry;
- Substantive structure: by adding CTS content, or CTS concepts as entailed in the selected contexts, and by discarding Pure Chemistry concepts not needed to make sense of the selected context used in teaching (Smith, 1988).

To sum up, Salters' Chemistry is taken here as a school chemistry course for which the CTS content is a *central* component. It constitutes, therefore, a bold attempt to escape from NCE.

The Salters' developers themselves (the pioneers, members of the development team, first teacher-users) made some explicit statements about the radical change they tried to achieve. First of all, Francesca Garforth, manager of the Salters' Chemistry project, stated that they wanted:

> To break away from the traditional mould and produce a *radical* rather than a piecemeal or *cosmetic* revision" (Garforth, 1983, p. 29).

Secondly, Holman (1987), who joined the Salters' Chemistry Project in 1984 as a developer of Year Three units, characterized the Salters' Chemistry course as "a *radical* approach, starting with everyday interests and experiences of students" (ibid., p. 436) which involved a "*radical* reappraisal of school chemistry" (p. 435). Holman described the central CTS approach of Salters' Chemistry as an "*applications first* course" (p. 434) contrasting it with the traditional, academic "*science first*" (p. 434) courses. The latter type of course might enrich its traditional content with add-on STS materials, such as SATIS units (1986), while retaining almost all the traditional *content* as well as the traditional linear *sequence*.

Thirdly, Smith (1988) analyzed the content and assessment procedures of various GCSE courses, including Salters' Chemistry. Two units of the latter course, *Metals* and *Warmth,* were trialled in his school which acted in 1984 as a Salters' Project school. He concluded that the "utilitarian aspects" (ibid., p. 109) of the Salters' Chemistry course made up a considerable part of the course, and that these aspects were also included in the assessment by specimen papers. The Salters' Chemistry course contained, in the terms used above, more CTS content than any other GSCE course he analyzed, and also more than was required by the draft National Criteria for Chemistry of 1985.

Finally, in the retrospective analysis of the Salters' Science approach by a number of its developers (Campbell et al., 1994, p. 423), it is maintained with regard to the *process* of development that:

> The design criteria approach thus encourages a *radical review of content*, and minimizes (though it does not remove) the influence of content selection decisions implicit in previous curricula.

The design criteria approach, an original attempt at curriculum development by the Salters' Project Team, will be discussed in section 4.3.4. The product of the developmental process, the Salters' Chemistry course, was claimed by those involved in the development, as well as perceived by a number of researchers and developers, as a *central CTS curriculum*, constituting a bold attempt to escape from dominant school chemistry or Normal Chemistry Education. For the theoretical reasons given above, the Salters' Chemistry curriculum was, therefore, considered by me as the most suitable candidate for the evaluative research undertaken here.

Practical reasons

Information about the Salters' Chemistry course prior to the conference was available in publications, and more information, such as syllabi and examples of teaching materials, was quite easy to collect at the Salters' presentations at the11th ICCE (held in York in 1991). At the conference I also arranged to have some meetings with John Lazonby who had been a member of the Salters' Chemistry Management Team (1984-1988). In those inspiring and extensive discussions, Lazonby also provided some striking examples of teaching activities, e.g., teaching chemical equilibrium by starting from a context of making a fertilizer, which illustrated that the Salters' Chemistry project made changes in traditional chemistry *teaching* and also, to a certain extent, in the chemical *content* of school chemistry.

Thereupon, I decided to try to perform a classroom-based case study of one or more Salters' Chemistry units. An in-depth qualitative case study could show to what extent *a change in chemistry teaching and content* had in fact been achieved by a classroom teacher while using units of the Salters' Chemistry course. (This classroom-based research is reported in Chapter 5.) Prior to that, an in-depth document and interview study could show to what extent *a change in chemistry teaching and content* had in fact been achieved by the developers in what I call the "design room", on which I will report in this chapter.

My research plan was discussed with David Waddington, Chairman of the University of York Science Education Group (UYSEG) which manages the Salters' Science Projects. This led to arrangements, made by his colleagues David Edwards and Peter Nicolson, for short visits to various schools that were using Salters' materials. The next year, a pilot study was performed by a teacher trainee from Utrecht, supervised by this researcher, which led to a report (De Gier, 1992) and which prepared the way for my own classroom-based research into two chemical units of Salters' Science, *Metals* and *Transporting Chemicals*. The results of the empirical research on the first unit, *Metals*, were subjected to further analysis in terms of my curriculum theoretical framework (see section 5.1.1 for the rationale). This led to a description and subsequent comparison of the visionary, designed, formal, interpreted, taught, and experienced curriculum levels of *Metals*, a unit of the Salters' Science course (reported on at length in Chapter 5).

To sum up, the Salters' Chemistry course provided not only an excellent *practical* opportunity for doing the research I wanted – it was accessible, suitable, and feasible, it also provided a good *theoretical* opportunity to test the effectiveness of a central CTS course to escape from Normal Chemistry Education. Or, in the words of the developers:

> The Salters' courses based upon an apparently *novel* structuring principle, provide a particular opportunity to explore the extent to which *structural variation* in chemistry syllabus design is possible in practice (Campbell, 1994, p. 443).

4.1.3 Method of curriculum evaluation

As Jackson (1992) notes in the *Handbook of Research on Curriculum*, curricula – science curricula not exempted – form a very complex field of study. This applies even more to the study of innovative science curricula, and to the study of their processes and products. Accordingly, "to provide a comprehensive understanding of the complex reality" (Parlett & Hamilton, 1977) constituted by an innovative chemistry curriculum such as Salters' Chemistry, I used the components of the curriculum theoretical framework as formulated in section 1.3.

The Salters' Chemistry course is characterized in terms of Roberts' concept of curriculum emphasis. The phases in the process and the intermittent products of the Salters' Chemistry development project are described in terms of Goodladian curriculum levels: visionary, designed, written, and formal curricula. To these curriculum levels is applied a further characterization in terms of Schwabian substructures: substantive, philosophical, and pedagogical. Finally, the concept of Normal Chemistry Education is used to explain the curriculum findings obtained.

Thus, in developing a framework and method of curriculum evaluation for the study of the development of the Salters' Chemistry curriculum (section 1.2.3), it is important to acknowledge the complex nature of science curricula:

> It becomes imperative to study an innovation through the medium of its performance and to adopt a research style and methodology that is appropriate" (Parlett & Hamilton, p. 21).

Thus, the researcher "concentrates on 'process' within the learning milieu, rather than on 'outcomes' derived from a specification of the instructional system" (ibid., p. 22). Parlett and Hamilton use the term *illuminative evaluation* for this kind of curriculum evaluation in order to distinguish it from comparative curriculum evaluation. Their reasoning implies a choice for a *qualitative* research design in which a substantial amount of time is spent in the classroom, for example, by performing a case study in order to investigate empirically the interpreted, taught, and experienced curricula. In this research this was done for the Salters' Science unit *Metals* (Chapter 5).

In considering the process of development of the Salters' Chemistry curriculum as a whole, we think it imperative to study also the important curriculum levels that were *prior* to those associated with teaching and learning that is, the formal, designed, and visionary levels. Thus, in this chapter another "medium of performance" of the Salters' Chemistry innovation is investigated by taking a look, as it were, into the *vision and design room* of the Salters' Chemistry project.

To what extent does the Salters' Chemistry course escape from Dominant School Chemistry? In order to answer this research question, I address the following curriculum levels later in Chapters 4 and 5. In so doing I focus on the process of transformation, from one curriculum level to the next, by asking to what extent these transformations proceed consistently, starting with the visionary curriculum.

- *Visionary* curriculum: the formulation by the developers of a vision of the new curriculum together with a number of design criteria;
- *Designed* curriculum: the first operationalization of the design criteria by designers or pioneer developers in a prototype;
- Written curriculum: the follow-up of the designed curriculum which is realized by elaborating or revising prototypical teaching materials after trials or testing in the classroom;
- *Formal* curriculum: the official codification of the written curriculum product in a syllabus by the developers in collaboration with the staff of an examination board;
- *Interpreted* curriculum: the curriculum (units) as perceived by teachers;
- *Taught* curriculum: teachers in the classroom executing the curriculum units;
- *Experienced* curriculum: students in the classroom experiencing the teaching of curriculum units.

Consistency analysis

Firstly, the curriculum vision of Salters' Chemistry is formulated in terms of a number of design criteria as given by the developers, criteria which must be articulated and operationalized during the process of designing concrete teaching units. In this chapter, I therefore analyze the Salters' Chemistry course in order to answer the question:

To what extent are the design criteria of the Salters' Chemistry course adhered to consistently by the developers?

This question will be answered for the following transformations: from the visionary curriculum to the designed curriculum (section 4.4), from the designed curriculum to the written curriculum (section 4.5), and from the written curriculum to the formal curriculum (section 4.6).

Secondly, it is not only the designed, written, and formal curriculum levels as such, "but their translation and enactment by teachers and students that is of concern to the evaluator and other interested parties" (Parlett & Hamilton, 1977, p. 21). Therefore, I systematically analyze "Metals" (Chapter 5), one of the units of this course, in order to answer the question:

To what extent are the design criteria of the unit adhered to consistently by developers designing the lessons of the unit Metals and by a teacher teaching the unit Metals?

This question is answered in Chapter 5 for the following transformations: from the formal curriculum to the interpreted curriculum, from the interpreted curriculum to the taught curriculum, and finally from the taught curriculum to the learned curriculum.

In both analyses I perform what I will call a *consistency analysis*, an analysis of a curriculum in terms of its own design criteria, which can be considered as a form of *illuminative* evaluation. This kind of analysis is reminiscent of the analysis performed by Joling et al. (1988) on the "Chemistry for the Citizen" course embodied in the "Chemie-mavo" project, discussed in section 1.1.1, and of the analysis performed by Herron (1970) on the structure-of-the-disciplines curricula such as PSSC, ChemStudy, and BSCS, discussed in section 3.2. In the case of the Salters' Chemistry curriculum, the consistency analysis is performed between the curriculum levels mentioned above, each time checking the consistency of the transformation of one curriculum level to another. This will lead to results to be used for the illuminative evaluation of the Salters' Chemistry curriculum.

Preview

The curriculum evaluation reported on in this chapter addresses, first, the background and genesis of the vision laid down in a number of *design criteria* by the pioneering developers (section 4.2); second, the further interpretation and articulation of this vision (4.3), its operationalization in a full year foundational course (4.4) and in a two year exam course (4.5), and finally its codification as the formal curriculum (4.6).

The curriculum evaluation of the aims and claims of a complex curriculum reality such as Salters' Chemistry, of its curriculum levels and structures, provide us with the qualitative information necessary to answer the question concerning the extent to which the Salters' Chemistry curriculum manages to escape from traditional school chemistry. In brief, this evaluation enables me to answer the question concerning the extent to which the Salters' Chemistry course escapes from Normal Chemistry Education.

4.2 Traditional school chemistry in England

Germane to the setting out of which Salters' Chemistry emerged was the *problem-situation* in secondary chemical education in England in the 1970s, as perceived and diagnosed by the developers, in particular by the Project Manager, Francesca Garforth (section 4.2.2). Regarding the analysis, the sources and the method of analysis which I have used to examine Salters' Chemistry are discussed in the first subsection (4.2.1). Using Schwab's terminology, I categorize (subsection 4.2.3) the critical remarks Garforth made with regard to the existing provision of school chemistry in England, in order to *compare* them with the visionary curriculum of the Salters' Chemistry curriculum (described in section 4.3).

4.2.1 Sources and method

My account of how the developmental process in the Salters' Chemistry project unfolded – from the visionary curriculum to the designed curriculum and its various trials in the classroom to the written, formal curriculum – is based largely on three extensive interviews held with Garforth.

Each interview took about one and a half hours, producing about 60 pages of transcript *in toto*. The three interviews, though different in emphasis, allowed the selection of a set of consistent quotes. For purposes of comparison, I also used quotes from interviews I held with three other members of the Salters' Management Team: David Waddington, John Lazonby, and Peter Nicolson. These four interviewees were given the opportunity to check the quotes (used in earlier drafts of this chapter) for accuracy, as well as to read the draft chapters and comment on my analysis. This was done in 1997 and later also in 2001.[2] In addition to the interviews, I refer to publications of Garforth and other researchers, developers, and teachers involved in the Salters' Chemistry project which were written either before, during, or after the development.

The first interview – a *double* interview with Francesca Garforth, Manager of the Salters' Chemistry project, and David Waddington, Professor in Chemistry at the University of York, and member of the Salters' Management Team – was held in September 1991 by Christie Borgford, an American chemical educator as part of her Ph.D. research.[3] This interview, referred to as (G/W91), was an open type of interview that Borgford started off with a leading question addressed to both Garforth and Waddington:[4]

> What are your perceptions of the conditions in chemical education in England in the late 70s and your response to that, which I think of as the *rationale* for the beginnings of Salters'? What is your recollection of the development *process*? (G/W91:1)

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2 Garforth (retired) gave individual responses, referred to as G97 and G2001, while Waddington formulated a common response, on behalf of the last three interviewees, referred to here as W2001.

3 See Borgford, C. (1992). *Change in science teaching and science content. Case study of an experiment with four traditional chemistry classes, using the Salters' approach* (Research Report). York, UK.

4 Quotes taken from the double interview are Garforth's unless otherwise indicated; numbers after the semicolon refer to page numbers of the transcripts of interviews.

The second interview was a semi-structured one, held by the researcher (BvB) with Francesca Garforth in October 1992. Most of my questions focused on the role which the *conceptual structure* of school chemistry, as described in subsections 1.2.2 and 2.3.2, might have played in the Salters' Chemistry development. This interview is referred to as (G92a). The third interview, also a semi-structured one, was held by another American chemical educator, Mary Beth Key, working on her Ph.D. research in York in November 1992.[5] Her interview focused on the evolvement of Garforth's views with respect to the *teaching and learning* of school chemistry. Key's main question was: "I just wondered, when did you start listening to your students?" This interview is referred to as (G92b).[6] Although a simplification, one could say that whereas Borgford focused in her interview on the "rationale" [Ped/A] of the Salters' Chemistry's project, and Key focused on the teaching approach [Ped/TA]. In my interview with Garforth, I focused on the role of the *conceptual structure* of school chemistry [Sub] and the underlying views on science and chemistry [Phil].[7]

The three interviews with Garforth turned out to be rich sources, especially of her original intentions and developing vision as Project Manager. Garforth's inspiration and influence has been acknowledged by her co-developers (Hill et al.,1989a).

As for secondary sources, I refer to a few relevant publications from the science education research and development literature, mostly in the notes so as not to disturb the 'storyline' of the Salters' Chemistry development process too much.[8]

In order to answer my research questions on the development and teaching of Salters' Chemistry in terms of *consistency* of the design criteria (section 4.1.3), and in view of the complex nature of the process of development, I think it is justified to describe this process in some detail. Also, using many and occasionally lengthy quotes from the developers might allow the reader to participate in the process and to discover or "rediscover the excitement of those years" (G97), as Francesca Garforth put it in retrospect.

4.2.2 Perception and diagnosis

Three factors determined Garforth's perception of the problem situation in chemical education in England in the late 1970s and beginning 1980s, namely: (i) her experiences as a grammar school teacher of chemistry; (ii) her findings on learning difficulties of O-level students with precursors to ionic equations in her M.Ed. thesis research; (iii) her experiences with the education work she had done, on behalf of the Royal Society of Chemistry, on chemistry core syllabuses, first for 11-14 year olds and then for 14-16 year olds.

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5 Key, M. E. (1998). *Student perceptions of chemical industry: Influences of course syllabi, teachers, firsthand experience*. D. Phil. University of York.

6 Both Christie Borgford and Mary Beth Key have kindly given me permission to quote freely from the interviews mentioned above.

7 For the meaning of these abbreviations used from here on, see subsection 2.1.3, Figure 2.2.

8 For example, Ziman's *Teaching and learning about science and society* (1980) proved to be an important and particularly relevant source. The general analysis of *conventional* science education that Ziman gives supports my own analysis. His concept of the "validity of scientific education" (ibid., p. 14), similar to the concept of Normal Science Education discussed in Chapter 2, is illustrated by the workings of the English educational system for the same time period, the late 1970s, as Garforth's analysis dealt with in section 4.2.2 above.

After having taught mainly very able students at grammar schools for most of her career, Garforth experienced the problem of *how to teach less able and less motivated pupils* for the first time in 1974 when her school became comprehensive. As she puts it herself:

> I began to realize a great many things about my own teaching ... that I hadn't made the slightest effort to tailor the subject to the child I was teaching. I just assumed it was just a matter of *from me to them* and it would be taken in. I hadn't thought of sequence of teaching. I hadn't thought of strategies for the less able. I hadn't thought what it was that *the less able, or even the moderately able*, were getting hung up on in chemistry: why they were finding it difficult. (G92b:1)

Her first attempt to remedy this state of affairs failed. It consisted of doing, together with her O-level colleague, a small educational experiment in which they tried to execute, and then compare, the results of two different *sequences* of teaching ionic equations. One teacher followed the standard textbook route with formula equations first and then deriving ionic equations from them, while the other taught ionic equations first and then formula equations. As Garforth remarked afterwards:

> So that [the experiment] didn't work, but what it did do was to enthuse me to come on the first year of the M. Ed. course here [organized by David Waddington in 1974 in York, titled Chemistry and Chemical Education] to do research on chemical education with Alex Johnstone and John Lazonby, and as my project, I thought I'd try and sort out the teaching of ionic equations ... first of all the precursors to ionic equations ... do you understand what an ion is, an atom, a proton, an electron, the difference between covalent and ionic ...; try and work out if we could find *a better route through* so that we got some *basic* ideas firmly instilled before we moved onto something that *needed* those *basic* ideas (G92b:2).

In 1976 Garforth published her findings in her M. Ed. thesis on learning difficulties with precursors to ionic equations.[9] One of her most remarkable conclusions was:

> It was the pre-A-level people, who were highly selected, in the top 15% of the ability range, and had chosen chemistry and were good at chemistry, who were still were having difficulties (G92b:3).

This conclusion was based on strongly correlated peaks, found in the answers to the differently formatted multiple choice questions she had put to O-level students, which pointed to learning difficulties that "had obviously come way back in understanding what was ionic and what was covalent" (G92b:3). Although the very able students had no problem at all with "taking it in" or with "passing the exams", at the same time "they weren't making any kind of sense out of the [ionic] equations" (G92b:3). As for the *less and moderately able* students – after many English schools became comprehensive, the *majority* of the student population were finding the traditional academic grammar school chemistry very difficult indeed, whether to take it in, or to pass the exams, that is, if they were entered for exams at all.[10]

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9 Garforth, F. M. (1976a). *Learning difficulties of O-Level students with precursors to ionic equations*. M.Ed., University of York. For a summary of her results, see Garforth (1976b) and (1976c).

10 Nuffield chemistry (11-14), which Garforth trialled from 1964-1967, seemed to work better for this age group because it focused more on *exploration*, on "doing and recording...[on] observing, asking questions" (G92a:6). But Nuffield chemistry (14-16) with its focus on "deep or atomic explanation" (G92a:7) was again, she felt, much too difficult for many students, except perhaps for the most able.

In 1978 in her capacity as a member of a small working party of the Royal Society of Chemistry (RSC), Garforth had the opportunity to work on a *proposal* for a possible *core* content of chemistry for children aged 11-14. The motive was that, at the time, "every school was allowed to do *its own thing* for the lower half" (G92a:6), that is, there was no coherence. The RSC working party presented, in the same year, a discussion paper which was received most "*favorably*" (G92a:6) by many of the thousand teachers to whom it was sent. The proposal was subsequently revised in the light of this consultation and sent to advisors and examination boards as "the RSC's idea of chemistry that *should* be taught in the early part of secondary education" (G92a:7). This core "genuinely reflected the views of teachers ... *it wasn't Salterish, but it wasn't academic*" (G92a:7). It was a *new* chemistry core, in which we "wanted to make sure there was some *basic* chemistry taught ... [and] ... attempted to bring about some kind of coherence for the nation's children at a time when there was no coherence at all" (G92a:6).

In 1979, Garforth had a sabbatical term in Cambridge as a teacher-fellow, which made it possible, as she explained:

> ... to devote time on behalf of the RSC trying to think out where the learning difficulties arose during standard CSE [Certificate of Secondary Education] courses where before I had been devoting my attention to GCE [General Certificate of Education] candidates, more able ones. I thought if the more able ones were suffering, *the less able ones were probably suffering more* ... (G/W91:1).

Relevant details of courses and examinations in England and Wales for secondary education in the period 1974-2000 can be found in Figure 4.1, kindly provided to me by Garforth, in 1997, on the occasion of her comments on an earlier draft of this chapter.[11]

On the whole our higher ability pupils did O-level [GCE], our next ability pupils did Mode 1 CSE, that is the one set by the Board and marked by the Board, and *the least able did Mode 3 CSE*, which was the one set and marked by *teachers* and moderated by the Board. (G92a:4)[12]

Figure 4.1 Examinations in England and Wales at age 16

Percentile of age group	1 – 30	30 – 60	60 – 80	(approximate percentile)
Exams: 1947 - 1974	GCE O-level	CSE Mode 1	CSE Mode 3	3 separate syllabi and exams
Grades	A – F	1 – 6	1 – 6	Grade 1 CSE = Grade C GCE
Exams: 1974 - 1986	"Common 16+"			1 syllabus; 1 exam
Grades	O-level grades	CSE grades		offered by some exam boards
	This exam co-existed with separate O-level & CSE			
Exams: 1986 -	← GCSE →			all exam boards; all pupils
Grades A	B C D E F G			

11 Most terms in this table are explained in the text. As for the term "16+", Garforth explained in her letter (G97) that this was a "very confusing" term which could refer to: (a) the age group of the pupils or (b) the common exam syllabus or (c) any exam (GCE or various modes of GSE) taken at age 16.

12 "Board" refers to the examination board.

Initially CSE syllabuses and courses had to be *different* from O-level/GCE syllabuses, and for a few years they probably were, according to Garforth. After all, they were *intended* for those children who did not go to grammar schools, but who went to so-called ‘secondary modern’ schools, introduced in the late 1940s. But then these teachers were told:

> In order to get *validation* from the examination boards they [the CSE syllabuses] had to be seen to be *comparable* to GCE. It’s awful, isn’t it (G92b:14).

This ruling meant that “the CSE people just slavishly followed the [GCE] O-level syllabus” (G92b:14), except perhaps for a minority of teachers who had already devised and taught *alternative* CSE syllabuses, and managed to keep teaching accordingly.[13]

Unlike the chemistry core for 11-14 year olds which was *designed* by the RSC working party, a proposal really of what *should* be taught in the early part of secondary education, the chemistry core for 14-16 year olds was *abstracted* by Garforth from existing syllabuses.

> And the only way I could really do this was to go through *every* exam syllabus there was, that is, *all* the O-level syllabuses and *all* the CSE syllabuses and *all* the common 16+ syllabuses that were then coming on the market ... and *extract* from them *a core*. So this was literally a core that *was* there, not a core I thought *ought* to be there. This was the core that was being taught to 14-16 year olds (G92a:6).

Garforth then circulated this core to teachers and others involved in chemistry teaching throughout the country “in the hope that it would provoke a riot ... this is what we are teaching, but couldn’t we do something else” (G92a:6). Contrary to teachers’ favorable response to the proposal of the 11-14 core syllabus, the response of teachers this time, as hoped for and to some extent anticipated by Garforth, was not favorable at all:

> Everybody who it was circulated to by the RSC shot it down in flames” (G/W91:1).

Thus, the first core (11-14) was seen by teachers as a real attempt to escape from tradition whereas the second core (14-16) was definitely not perceived as such:

> Obviously something needs to be done; but this isn’t the way to set about it. All you have done is to collate the least controversial aspects of a number of CSE syllabuses and put them together. What you need to do is to take a completely *fresh* sheet of paper and start all over again (G/W91:3).

What was needed was a new vision, and some method to elaborate and implement such a vision. As for now, there seemed to be, on the part of teachers:

> ... a feeling of utter dejection that things never changed: the picture of chemistry was just as difficult, just as *traditional*, and *they didn’t seem to be able to break out of the circle ... cycle* (G92b:13).

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13 Garforth herself decided, in this period, first to enter her candidates for an adapted, that is, more user-friendly *O-level* exam. “*We* [Joint Matriculation Board] were taking out a lot of the hard arithmetic, and the more complicated equations, we took out permanganate and dichromate equations for the O-level. *It was still on CSE!*”. And later she devised “a very simple minded Mode 3 syllabus” with easy, though strictly marked questions, which was therefore awarded grade 1 by the examiner (G92b:14).

Or, to put it in terms I use in this thesis, many teachers and others involved in chemistry education in England in the late 1970s suddenly seemed to realize three things about the existing provision for school chemistry: (i) the rigidity of traditional syllabuses, that is, of Normal Chemistry Education (NCE); (ii) the necessity and willingness to break away or escape from NCE; with at the same time, (iii) the strongly felt improbability of being able to escape from NCE.

Let me summarize Garforth's perception of the situation in chemical education in England in the 1970s, and her diagnosis, as follows. Firstly, the provision for 11-14 year olds, *should* contain some basic and coherent chemistry, but not be academic. Secondly, the existing academic provision for chemistry for 14-16 year olds *can be taught to the exam*, but only to the more able, a minority of the students (about 20 % of the age group). Thirdly, research has shown that it *cannot* be taught successfully for *understanding*, neither to all of the more able students, nor a fortiori to most of the moderately and less able students, the majority in comprehensive schools. Therefore, it seemed unreasonable to continue the practice of teaching this majority a similar academic content as contained in traditional grammar school chemistry syllabuses.[14]

4.2.3 Discussion

At various places in the interviews Garforth gives a succinct description, as well as a critical analysis, of many aspects of the then existing provision for chemistry for 14-16 year olds in England from which many teachers wanted to get away. That provision is taken in this thesis as a representation of normal chemistry education (NCE) in England in the 1970s.

I categorize her characterizations and critical remarks with regard to the different curriculum levels of the Salters' Chemistry project in terms of Schwab's curriculum structures. (The structures were introduced in Chapter 1, and codes in Chapter 2, Figure 2.2.) This categorization is continued throughout this chapter, both for Garforth's perception of NCE in England and for the visionary curriculum and its realization which, if it had been successful, would have had to replace part of the NCE as it existed in England at the time.

I begin my discussion with components of the pedagogical structure [Ped]. The aim [Ped/A] of traditional or grammar school chemistry which Garforth perceived at the time for students was:

> Passing the exams [O-level] and going on to A-level, passing the exams and going on to university and becoming doctors or vets or whatever it was they wanted to become (G92b:1).

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14 Ziman (1980, p. 16) explains the mechanism at work here as follows: "the '*validity*' of scientific education ... leads to debates which are often resolved by a compromise that ... transfers the *pressure* to the earlier stages of education" (ibid., p. 9). In this case the content of the new CSE syllabuses had to be *comparable* to the *validity* of O-level, which should prepare for A-level chemistry, the validity of which derives then, ultimately, from "*valid* science" (ibid., p. 22) as it is recognized by research scientists. See Garforth (1983, p. 29) for a similar statement. Chapter 2 of this thesis gives a functional explanation of this mechanism in terms of *normal science education*.

Garforth characterizes the traditional teaching approach [Ped/TA] as an activity in which teachers *transmit* what was required by the syllabus: "*from me to them* ... to people who had to be fed" (G92b:4). The information to be transmitted came from chemistry textbooks most of which were theory-based, and had a linear sequence. When she later trialled Nuffield chemistry, it led her to the realization that students were "people with a problem" (G92b:4). Her teaching then changed into "a communal activity in trying to get the class to devise solutions" (G92b:4), a problem solving approach [Ped/TA] within the bounds of academic school chemistry (NCE).

Garforth also makes a few remarks on aspects of the philosophical structure [Phil] of traditional school chemistry which, as she says, is introduced through "*a solid foundation of theory*" (G91b:3), that is, the idea "to work from theory up to experiment" (G92a:2). Traditional school chemistry, including Nuffield chemistry, was so "hung up on explanation at the atomic and sub-atomic level" (G92b:17), and as a consequence, "we plunge[d] them [the children] straight into the submicroscopic" (G92a:2); that is, "we were asking the fourteen year olds for a lot of *abstract* conceptual ideas which *they just couldn't cope with*" (G92b:3). This led her to a second, maybe even more important realization: "What *justification* is there for it?" (G92b:3).

> Do we have *any justification* in making chemistry the sort of subject where we insist that they understand in terms of electrons and protons and movements of atoms and molecule [and] we say, well you've got to *accept* this for the moment. You can't possibly understand it (G 92b:4).

The theoretical framework in terms of which Garforth formulated and interpreted some of her conclusions above owed much, she said, to the work of Alex Johnstone[15] "into the concrete/abstract accessibility content of school physics, chemistry, and biology" (G92a:2). For example, Johnstone's research does not support the suitability of an abstract, theoretical approach to teaching chemistry for 14-16 year olds, let alone for 11-14 year olds.[16]

Waddington has aptly described the type of school chemistry with a strong emphasis on *solid foundation of theory* – one of the curriculum emphases identified by Roberts' (1982) – as teaching or learning by "deferred gratification" (p.c.). That is, it is only at a later stage that some students will see the point of their O-level chemistry (see also section 3.4.1). This *can* only apply to the minority of students in an O-level classroom who will take A-level chemistry, and really only to those few students who then go on to study chemistry as a major or minor subject, that is, for those very few students for whom there *is* such a later stage in their studies.

In Garforth's opinion, conventional school chemistry focuses on "chemicals in the laboratory as distinct from kitchen objects" (G92b:9). And it had to be "real chemistry" (G91:18) in the minds of "the great and the good – I mean the people who were really chemists" (G92b:9). The answers to the questions which textbooks provide are "either

15 In the interviews Garforth discusses, for example, the accessibility, for the teaching of school chemistry, of the macroscopic (concrete) and submicroscopic (abstract) levels in chemistry and the relation of both levels to a third, representational level as distinguished by Johnstone (1982; 1993).

16 This is also not supported by the Piaget-based research of Shayer and Adey (1981).

right or wrong" (G92b:5); gray areas are not acceptable, either for students or for most teachers.[17]

Garforth's and Waddington's characterization of the existing provision for school chemistry for 14-16 year olds in England can be taken as a combination of two of Roberts' (1982) curriculum emphases: "S*olid Foundation*", stressing science as cumulative knowledge, and "Correct Explanations", science as reliable, valid knowledge (sections 1.3.3 and 3.3.3).

In the context of the interviews, Garforth characterizes the substantive structure [Sub] of traditional school chemistry, as it then existed in England, in rather general terms.[18] Conventional syllabi are dominated by theoretical chemical concepts on the whole, and by submicroscopic concepts in particular, and by "things you do in the lab, like heating, mixing with water, trying with indicator paper ... separating" (G92b:8). In brief, they are dominated by corpuscular chemical concepts and relationships [Sub/CR], and by standard chemical techniques [Sub/CT].

To sum up, traditional school chemistry, as perceived by Garforth, serves an academic purpose. It teaches in a transmissive and top-down way a kind of chemical knowledge which can be characterized as abstract in general, and submicroscopic in particular, with chemical techniques employed on chemicals in the laboratory.

4.2.4 Conclusion

It is now possible to formulate more precisely, and in terms used in this thesis, what the team of developers in York led by Garforth were planning to do.

First, they wanted "to break away from the *traditional* mould" (Garforth, 1983, p. 29), that is, from the *rigid* combination of the substantive, philosophical, and pedagogical structures which existed in dominant school chemistry. In other words, they wanted to escape from normal science education as it existed in England in the 1970s. Garforth's characterization of the O-level curriculum in England is summarized in Figure 4.2 below.

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17 Nuffield developers attempted to make a change here too, in that it favored an open-ended approach with open-ended questions. In practice, however, the discovery approach proposed, with the pupil seen as a scientist, was difficult to realize even with bright pupils. One reason for this according to Garforth was: "you didn't want the children to ask questions that you hadn't the equipment for. Or even led to an argument that wasn't on the syllabus!" (G92b:7). Another problem turned out to be the lack of a regular textbook in Nuffield's trial phase. Hence, "in response to teacher demand, and pupil demand, and parent demand, the Nuffield team began to produce textbooks" (G92b:6). This, of course, came to detract even more from the open-ended character of the Nuffield courses. See also Schwab (1962, p. 55) for a lucid discussion of problems with regard to the real and "apparent openness" of much laboratory work, which is often "structured" and for which results are provided by the textbook. Ziman (1980, p. 27) makes the fundamental point: "*There is no real escape in this direction from the rigours of valid science;* what is to be 'discovered' thus must not be different from the scientific truth which the teacher is duty bound to transmit".

18 At some points, though, Garforth does give details of the conceptual structure of traditional school chemistry, which coincide largely with the picture of dominant school chemistry as it came out of the fora (IF/DF) in this research (described in Chapter 2). Her response to one of our papers (De Vos et al., 1991) confirms this.

Her characterization *compared* with the currently dominant school chemistry curriculum (See Figures 2.3, 2.4. and 2.5) enables us to determine whether the O-level school chemistry curriculum can be considered as a form of Dominant School Chemistry (DSC) and thereby as a representation of NCE in England.

The *pedagogical* structures of both school curricula (the former O-level and the currently dominant school chemistry curricula) contain similar characterizations:

– of aims in terms of academic preparation of future chemists and exam-driven curricula;
– of the teaching approach using terms as *textbook-oriented*, *theory-led*, and to transmit;
– of the learning approach using terms such as reproduction or rote learning.

The *philosophical* structure of DSC is largely similar to that of the O-level curriculum: both emphasize a solid foundation of theory, corpuscular chemistry, and the certainty of answers to questions put to students. Though the *substantive* structure of DSC has been described in more detail with regard to the set of standard chemical ideas, it too will be considered as largely similar to the substantive structure of the O-level curriculum. Both curricula stress the application of laboratory techniques to simplified chemical systems. Therefore, the O-level curriculum as described by Garforth can be taken as a form of DSC, and as a representation of NCE in England at the lower secondary level.

Second, the developers would try to design, trial, and develop a *radical alternative* school chemistry "with *chemical awareness* for future *citizens* as a *principal* aim" (Garforth, 1983, p. 30), *a vision* addressing the need of the majority of students.

Third, the developers would proceed as follows. They would *try to discover, during the developmental process*, the exact components of an *alternative* combination of pedagogical, philosophical, and substantive structures, which would make up a justifiable, appropriate, and feasible school chemistry for the 13-16 year olds. The last point has been formulated, in retrospect, by the developers as follows:

> Only through the development of detailed teaching materials does it become clear what the broad aims mean – indeed whether or not they are *feasible* and, in that sense, have any *meaning*. Curriculum development is the process of *discovering* the detailed aims and objectives rather than starting with them (Campbell et al., 1994, p. 420).

The remarks of the developers made under these three points could be interpreted as touching on the three conditions for escape described in Chapter 3 (Figure 3.11), a topic to which I shall return in the next section.

Figure 4.2 The O-level chemistry curriculum

CURRICULUM CATEGORIES	O-LEVEL CHEMISTRY GCE / CSE CORE 14 – 16
Pedagogical structure	**Initiatory and preparatory for further study**
Aims	Academic preparation future scientists; Focus on needs of most able students, i.e. a minority of at most 20% taking exams.
Teaching approach	Top-down/transmit/from me to them; from theory up to experiment. Textbook and exam based.
Learning approach	Taking it in, textbook based. Syllabus/exam-driven.
Philosophical structure	**Educational Positivism**
Foundations of Science	Solid foundation of theory.
Methodology of Science	Problem solving: answers to questions either right or wrong.
Foundations of Chemistry	Submicroscopic level dominates. Atomic and subatomic explanation. Real, pure chemistry.
Methodology of Chemistry	Problem solving: answers to questions either right or wrong. Laboratory experiments.
Substantive structure	**Corpuscular Approach**
Chemical Concepts	Abstract conceptual ideas.
Chemical Relationships	Standard, e.g. corpuscular theory, periodic system, classification.
Chemical Techniques	Lab techniques applied to simple systems, i.e. to lab chemicals.

[a] Most keywords are drawn from interviews and publications of developers; some paraphrasing has been added.

4.3 The visionary and designed curriculum of Salters' Chemistry

Garforth's revealing experiences with the existing provision for school chemistry as a teacher, developer, and researcher had as a consequence that she became, on the one hand, "very disheartened about teaching" (G92b:11), but on the other, more determined and focused in her attempt to develop "a genuinely appropriate 16+ chemistry syllabus" (Garforth, 1983). It was in this spirit that she applied for a fellowship at the Leverhulme Trust, in order to create the circumstances for doing, what was for her, necessary chemical education work (G/W91:3).

This meant the articulation of a vision (section 4.3.2) and of an appropriate method of development of corresponding units (section 4.3.3). Together this led to the Salters' Chemistry project organized by the Science Education Group of the University of York. My description of the process of development, though, will begin with the developers' perception of three major obstacles on the road to the development of *any* alternative, relevant school chemistry course (section 4.3.1).

Where appropriate I will make a connection between the Salters' Chemistry management team's remarks on the process of development and the three conditions for escape discussed in section 3.4, and listed in Figure 3.11.

4.3.1 Three obstacles

In view of her diagnosis, Garforth had few doubts, either about the *necessity* or about the *desirability* of devising a new *relevant* chemistry syllabus which would depart *radically* from the content and teaching of traditional academic oriented school chemistry courses. But, would it be *possible* fully to "break away from the traditional mould", in other words, to escape from Dominant School Chemistry (DSC) as it existed in England at the time?

This led in the early eighties to a first workshop at the University of York, consisting of a small group of chemistry teachers, six from secondary schools and four from higher education, who set out 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).

Garforth's article, written April 1983 on behalf of the team of teachers-developers after their first workshop, has the significant title "*Chemistry to 16+ Examination: Work in Progress – Help Needed!*" Three obstacles are mentioned in it, of which the first is:

> First year University *content* [Sub] often appears to *determine* A-level *content* which in turn *determines* O-level *content*. Parity of Grade 1 CSE mode 1 with grades A – C at O-level *determines content* of CSE courses and both in turn *inevitably govern* the chemistry curriculum in the early years of secondary schooling. In view of the relatively small proportion of the age group continuing to A-level (about 7%) and an even smaller proportion using chemistry in higher education, it is *surely unreasonable that their needs* [Ped/A] should so overwhelmingly *prescribe content* [Sub] *and teaching methods* [Ped/TA] for chemistry 11 – 16 (ibid., 1983, p. 29, my italics; see also Figure 4.1).

Or, to put it in terms used in this thesis, is it possible to escape fully from the constraints which the pedagogical structure of DSC puts on the kind of content and teaching of chemistry at the secondary level?[19] The second obstacle is described as follows:

It may well be that there is a *corpus of knowledge* [Sub] without which no syllabus could be called chemistry ... equally it may be that by our *own schooling, subsequent training and teaching we cannot see anything different* adequately filling the space called chemistry at this level (ibid., p. 29).

To put it in terms used in this thesis, is it possible for teachers, developers, and researchers in chemical education to escape fully from the substantive structure coordinated to the pedagogical structure of DSC (mentioned above)?

The third obstacle was, as Garforth and her co-developers found out, they were unable to agree beforehand what they meant by chemistry at this level of schooling. This raised the following questions:

> If it [Sub] really must be what we *recognize* now as an O-level syllabus, then should it be taught to any but *the most able* [Ped]? If the *academic nature* of chemistry [Phil] is *implicit* and *inevitable,* is it *worthwhile* attempting to rewrite chemistry syllabuses in terms of familiar, relevant, and socially and economically important materials and ideas? (ibid., p. 29)

We will see further below, that the developers did not make explicit in any detail what the structure was composed of, or what they called (above): "a corpus of knowledge without which no syllabus could be called chemistry". That is, they did not try to fulfill *condition one*: Perform a domain specific analysis of the nature and structure of the dominant school chemistry curriculum (see Figure 3.11).

What developers say here can be interpreted as follows: the constraints imposed by the pedagogical and substantive structures are *rigidly* coordinated with constraints imposed by the philosophical structure with regard to the proper nature of school chemistry. In Chapter 2 I gave an explanation of the rigidity of Dominant School Chemistry, in terms of the concept of Normal Science Education, more specific the concept of Normal Chemistry Education.

To sum up, it seemed difficult, if not improbable to the developers that they would be able to escape fully from the *rigid* combination of [Ped], [Sub], and [Phil] contained in Dominant School Chemistry.[20] But if this seemed so improbable, and since it was far more likely that it would only be possible to *graft* some relevant teaching material onto existing syllabuses, the question emerged, would "it be worth doing anything at all?" (ibid., p. 30). Such a conclusion, though, was regarded by the group at York as a "counsel of despair" (ibid., p. 30). They decided, as Waddington[21] has emphasized, "*to try a test*" (G/W91:3). This meant that the developers would accept the *challenge* to design a chemistry course which would "teach science for life ... life skills or whatever it is ... to *find out* what that meant ... what chemistry you taught" (G/W91:3). Addressing Garforth

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19 Ziman (1980, p. 16) concludes that "the fundamental *vocational* purpose [Ped/A] of science education thus imposes upon it a certain degree of *uniformity* [Ped/TA] that seems to match the *universality* of science [Sub] itself ".

20 As Ziman (1980, p. 29) puts it: "What I have tried to demonstrate ... is that the actual *form* of science education is *quite strictly determined by its content*, and is not susceptible to arbitrarily large variations."

21 See, for example, Campbell et al. (1994, p. 419), where it is pointed out that the "implications ... had to be worked out *by trying to do it*" (italics theirs).

in the double interview, Waddington concludes: "I think that married up with what you wanted" (G/W91:3), that is, designing a school chemistry course aiming at *chemical awareness for future citizens*.

4.3.2 Tentative vision

Let me now describe more in detail the views Garforth, as Salters' Chemistry project manager, arrived at with regard to both her vision and the way this vision could be realized. Where appropriate I will relate these views to the conditions of escape listed in Figure 3.11.

Background

At a general level Garforth's vision had been nurtured by the study of publications and teaching materials produced by the science education community in England in that period. For example, the Association of Science Education (ASE) had been pleading for "Alternatives for Science Education" (1979), in terms of "Education through Science" (1981), the ideas of relevance and "Science for All" (1983). Furthermore, Garforth had done part of her chemical education work with Malcolm Frazer at the University of East Anglia, who, as she said, had influenced her with preliminary work on a teaching approach which started differently: "they'd had ideas about toothpaste" (G/W91:3). She also became acquainted with *existing alternative* resources: "a lot of very good science texts" (Garforth 1983, p. 30) for less able pupils which were rarely used. These included mixed science courses such as *Nuffield Secondary Science* (1971),[22] the *Less Academic Motivated Pupils* (LAMP) project (1976), and *Working with Science* (1978), all of which "provide courses based on materials and situations in the everyday world but which *deliberately do not attempt to explore explanations or understanding in terms of chemical concepts and principles*" (ibid., p. 30).

Finally, it was the exemplary local practice of chemistry teachers and the experience of comprehensive schools with CSE Mode 3 syllabuses for the less able pupils which prepared the way for what Garforth wanted to do. This eventually came to involve a lot of "hard work; writing materials, trials of these materials, evaluation, and rewriting" (ibid., p. 30); and further ahead, getting accepted by an exam board which was necessary for their later attempt at full-scale implementation at the national level.

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22 Shayer and Adey (1981) claim, on the basis of their Piaget-based research, that Nuffield Secondary Science (13-16 range) – unlike Nuffield O-level Chemistry (11-16 range) and even Nuffield Combined Science (11-13 range) – is a course "initially well within reach of *concrete* operational thinking" (p. 122). Therefore, the *cognitive demand* or level of Nuffield Secondary Science "matched" rather well the abilities of "the great majority of children ... who might follow CSE or non-examination courses" (p. 121). Unlike the popular Nuffield Combined Science, though, this course was "relatively little used" (p. 149)!

Components of visionary curriculum

As for the aim of an alternative chemistry course, it was clear that in the first place it was meant to be a provision for the *majority* of pupils of *less and middle ability* which *might* also be suitable for the more able and thus in the end, for the full ability range [Ped/A]. Other components of the vision of the Salters Chemistry developers are nicely captured in the following quote:

> What we wanted to do was to tap peoples' views as to, first of all, whether *chemistry* [Sub] needed to be approached *differently*. And, secondly, whether it was possible *to do it any differently* [Ped/TA], I mean whether we could get away from starting with a *solid foundation of theory* [Phil] which a lot of children were *unable* to grasp at the age of fourteen and a lot never even *wanted* to grasp at the age of fourteen. And whether it would be a good idea, or a possible idea, to start them in on things which were the result of the *applications* of chemistry [Ped/TA] (G/W91:3).

Thus, the developers' view as to what *chemistry* should mean at this stage of schooling was changing – to put it succinctly: away from theoretical chemistry and towards *applied* chemistry.[23] Also, their views on teaching shifted from a 'top down' to a 'bottom up' approach, that is, from a theory-first approach to an approach which would put pupils' experiences first, either with *familiar materials* or with *applications of chemistry*. Thus, in my terms they were looking for a different combination of substantive, philosophical, and pedagogical structures that would cater for the majority of pupils.

Both vision and method of development were made more explicit in and *because of* the developmental process.[24] During a long weekend in September 1982, the developers reached a consensus which consisted of the five components given below (Garforth, 1983, p. 29). I will elaborate on each component by using comments that Garforth and other developers made in the interviews. The first component of their vision was:

> 1. That the activities which are carried out in a *chemistry laboratory* provide a *valuable* educative process for *all* pupils.

Garforth elaborates on this: "I'm sure there is a *motivation* in the actual *doing* of things and that we had to remember we are dealing with a chemistry syllabus, we are dealing with people [i.e. pupils] who are going to be working where there is chemical apparatus and they might just as well use it" (G92a:13). Therefore, the developers decided to use, optimally, the existing resources of the school laboratory, that is, "lab things, such as to filter, evaporate, distil, treat with acid, bash up with hammers ... " (G92a:12) should be in the course, and done by pupils. Activities in the laboratory should be approached differently, though, in order to turn these resources into "*worthwhile*" chemistry for *all* pupils. So, "*our problem* was looking for *familiar materials* with which we would do things that in the *lab* we had used to do with something quite *unfamiliar* like *sodium or zinc*" (G92a:15).

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23 See also Harding et al.(1986), a researcher in chemical education who also contributed to the development of Salters' Chemistry. Harding argues that: "Chemistry is supremely a technological activity: we use, modify, purify and create materials and are concerned with the discipline of chemistry as a tool for enabling these activities" (p. 48). She feels strongly that "[a]n essential requisite for development is a change in view as to what chemistry *is*, the rest follows! (p. 51, italics hers).

24 As the developers themselves state in retrospect: "the process of developing in detail a curriculum to promote scientific literacy is *an act of discovery* – finding out what such a curriculum might look like" (Campbell et al., 1994, p. 422; italics theirs).

This new starting point had an important consequence:

> And then we looked at these [things every child will have met in its everyday life] and thought, what can the children do with them, or what will happen if you do the ordinary kind of things that you do in the lab, like heating, mixing with water, trying with indicator paper, *so obviously at that point we'd got a set of ideas of experiments in our mind, but we were still holding out against concept sets* (G92b:8).

This led to the second component of their vision, namely:

2. For *some* pupils these activities may not develop beyond the *manipulative* and *observational* levels.

For these pupils, probably the majority of the less and moderately able, the emphasis should be on the "exploratory, yes ... and explanatory as long as you don't go too far" (G92a:20).

Activities at the manipulative and observational levels could concern things such as:

– the *making* of things, for example, "growing the biggest crystal in school" (G92a:13); or "raise scones" using baking powder which can give very young children, at home, in the kitchen, some idea about "*the principle* that an acid would react with the carbonate to give carbon dioxide to raise the scones with" (G92a:19).
– *doing* things such as "finding out what is in something ... in a great heap of shining, silvery metal", which a 15 year old pupil found and "her dad said it dropped off the back of a lorry". This turned out to be nickel, in the improvised "lovely lesson" following this up with "lovely green solutions". And by the next lesson this group of "moderate ability children ... had done *the reactivity series of metals*." (G92a:13)
– *observing* everyday life things, for example "something you can meet in your own kitchen", like seeing "plates with blackcurrant pie on it ... go green", while cleaning them with washing liquid. This then led , after a question of her granddaughter aged 7: "Does it do it with all the fruit?", to doing chromatograms with blotting paper and to the notion that not all fruits contain the same *indicator* (G92a:19).

Note that these are all examples of using existing resources optimally, either from the kitchen or the school lab, by exploiting the idea that "if you've got a resource there, see how you can use it" (G92a:13). Each activity leads to a simple and qualitative introduction of a basic chemical idea, respectively: the reaction of an acid with a base, the reactivity series of metals, and the idea of an indicator. These chemical ideas were set in a *daily life context* and appeared accessible to young pupils of average ability, a majority in secondary schooling. The principle behind these examples was later called *context and activity-based science* (Ramsden, 1994).

The third component of the developers' vision emphasized that:

3. *Other* pupils will *want* (and *need*) to explore the observations in terms of *chemical concepts and principles*.

This point would mostly concern some of the moderately able students and, especially, all of the *most able* students whose needs had always been taken care of by grammar schools in the past, that is, their perceived needs had "overwhelmingly prescribed teaching methods and content" (Garforth, 1983, p. 29). As the developers found out in that first workshop in York (1982), and much to their relief, it proved possible to *derive* chemical concepts and principles, including those needed for purposes of *explanation*, from "experiments with and reading about" materials and situations in the everyday world. For example, in activities related to what was called the *theme Crime*, "experiments on fingerprinting led to such *fundamental* scientific concepts as change of state ... and classification, those on casting methods for footprints to ... structure and synthesis, those on saliva and blood testing to catalysis and analysis" (ibid., p. 30).

This first design can be considered as an exemplar or prototype of what they wanted. It seemed that this *theme-led* approach (later called by them "context-led approach") envisaged by the developers could work for pupils of *all* abilities, including the most able ones who wanted and needed fundamental chemical concepts and explanations.

The fourth component of their vision emphasized that:

4. *All* pupils will benefit from learning about the *sources and properties of familiar materials*.

As Garforth explains, "You see, in the old syllabuses, in the old teaching of chemistry you learnt about what to you and me are *simple systems*,[25] like sodium or chlorine, copper, and oxygen. Things children might never meet in their lives again, before or since, apart from oxygen" (G92a:14). The new "16+ chemistry syllabus genuinely appropriate for all future citizens" (ibid., p. 30) would be concerned with familiar materials: where they came from, which properties would be *useful* and for what *purpose*, and the effects of winning materials from the environment. For example, there could be lessons starting from themes such as "water, detergents, fuels" (p. 30). (See also the examples mentioned in the discussion of component 2.)

This led to the last component of their vision, namely:

5. It may be possible to develop concepts and principles through the work carried out on *everyday* materials and themes.

In the discussion following components two and three of their vision some examples were mentioned where the fifth component also appeared to be possible for the moderately able students working with the ideas: reaction of an acid with a base, reactivity series of metals, and indicator; and for the more able students working with such fundamental scientific concepts as change of state, structure, synthesis, and catalysis. In sum, this first workshop at the University of York had managed to produce at least a prototype of their vision.

By formulating their vision in terms of these five components of the visionary curriculum, and by producing a first prototype thereof, the developers fulfilled to a large extent condition two: Develop a new coherent vision on the structure of a school chemistry curriculum (see Figure 3.11).

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[25] See sections 1.2.2 and 2.3.2 for a similar point about what I called there, pure (school) chemistry.

Figure 4.3 Visionary curriculum of Salters' Chemistry[a]

CURRICULUM CATEGORIES	
Pedagogical structure	**Essential chemistry for living**
Aims	Chemical awareness for future citizens: learning about sources and properties of familiar materials. Focus more on needs of less able and moderately able students: a majority of ca. 80%.
Teaching approach	Bottom-up; Communal problem solving activity: theme, context, applications based.
Learning approach	Worksheets, no textbook; Accessible knowledge; Doing work, especially lab work.
Philosophical structure	**Relevance and Use**
Foundations of Science	Daily life phenomena/applications; Only most able need or want more theory, chemical concepts and principles, including those needed for purposes of deep explanation.
Methodology of Science	Communal problem solving activity, including social, economic oriented problems.
Foundations of Chemistry	Focus on exploration, on macroscopic level. Daily life chemistry e.g. home/kitchen. Explanation but not too far down the microscopic level.
Methodology of Chemistry	Making things; Analyzing of things made.
Substantive structure	**Familiar Materials Approach**
Chemical Concepts	Holding out against concepts sets; No preconceptions.
Chemical Relationships	Coherent basics; Recognizable sequential order.
Chemical Techniques	Lab techniques applied to familiar materials such as household materials and common phenomena.

[a] Most keywords are drawn from interviews and publications of developers; some paraphrasing has been added.

4.3.3 Method of curriculum development

Based on the five components of the visionary curriculum described above, the vision of the developers on the *process* of development was further articulated and characterized in terms of so-called *design criteria*, some of which were already implicitly present in Garforth (1983). I will first discuss what the developers have called the *design criteria approach* to curriculum development. This is followed by a brief account of the developers' organization of drafting and writing of teaching materials.

Design criteria approach

As the developers (Campbell et al., 1994, pp. 418, 420) stated in retrospect, the design criteria they choose were: "quite *general* criteria, providing direction but *not limiting the outcomes* at the level of detail". They thereby clearly distinguished their *design criteria approach* to curriculum development *from the more specific and constraining set of objectives* that a traditional curriculum development model uses. Initially, three general design criteria were formulated.

> ***Criterion one: No preconceptions***
> Start with "a completely fresh mind, a clean sheet of paper, and no preconceptions" (Garforth, 1983, p. 29). Getting rid of their own preconceptions was the most important criterion according to the developers, but they also thought it the most difficult to adhere to. It has been formulated in various ways, for instance, "We did try and rid ourselves of preconceptions as to what should be in a chemistry course" (G92b:8).
>
> ***Criterion two: Relevance***
> In view of the student-centered aim and the teaching approach adopted, "we were at great pains to *put familiar everyday experiences first*" (see components 1 and 4 of vision above).
>
> ***Criterion three: Context-led concept development***
> The developers wanted to find out whether "It may be possible to *develop concepts and principles through the work carried out on everyday materials and themes*"(see components 2, 3, and 5 of vision above).

By formulating their view on curriculum development in terms of these design criteria, the developers fulfilled, at least in a general way, condition three: Use a systematic method to articulate, operationalize, and implement the new, conjectural vision. In this and the following chapter on the Salters development process we will see more specifically, to what extent the developers were able to fulfill the conditions listed in Figure 3.11, in particular:

- 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.
- Collect evaluation data at all curriculum levels to safeguard the adopted vision.

As noted above, the initial vision of the developers had much in common with what went on in curriculum reform in England in those years. There were also differences emerging, specific to the group at York, such as the *explicit* focus on the *full* ability range, on a relevant chemistry course for *all* students which includes the needs of the most able pupils. As Garforth put it:

> I used those teachers and their syllabuses shamelessly in trying to work out how we could use *the same approach* – an *experimental* approach to teaching chemistry [but] to the *full ability* range (G92a:4).

This implied that the "*essential chemistry of living*" (Garforth, 1983), the curriculum emphasis which the developers were trying to capture, should serve *both* the needs of a "scientifically aware electorate and [be] a basis for further study in chemistry" (p. 30).

As we will see below, this focus on the full ability range has consequences for the application of the third design criterion. It leads to an increased emphasis, not only for the most able but for *all* students, on *explanations* in terms of *abstract* chemical concepts and principles compared to exemplary CSE syllabuses or schemes for less academically minded pupils.

As has been evident from the interviews, the Salters' developers came to set great store by the first criterion, which can be seen as a kind of *a priori* conception or a so-called "tenet of faith" (G/W91), that developers and teachers participating in the developmental process should try to hold on to as much as possible.

Since the process of curriculum development is conceived as "the act of articulation of these broad aspirations" (Campbell, et al., 1994, p. 420), we will see that the design criteria stated above are reformulated in the process of development and adapted to the purpose at hand. The great advantages of the design criteria approach are that it is open to change, either to explication or evolvement of relevant design criteria, and that it invites the active participation of developers and teachers working on prototypes, trials, and revision of units. For example, in the process of development was also 'discovered' another design criteria, namely: *variety of teaching and learning activities.*

Organization

The actual writing of drafts of teaching material along these lines, that is, starting from general design criteria, was organized as follows. Teachers, six from secondary schools and four from higher education, were brought together at the University of York in September 1982 for the first Salters' workshop. Among the secondary teachers were "those who had responded most vituperatively to my mock [core] CSE syllabus sent out the previous year" (G/W91:3), that is "people who had written to me to say, here's my Mode 3 syllabus" (G92b:12).

> So, we got the ones who sounded as though they had the most to offer – school teachers on the one hand and an equal number of tertiary educators on the other hand. And with the money from the Salters' company we had them here for a long weekend. *So, that was officially the start* (G/W91:3).

These very *enthusiastic* teachers had a great "willingness to explore a completely *fresh* approach" (Garforth, 1983, p. 29) while trying to follow criterion one, *no preconceptions*. They were asked to submit in advance "a list of *familiar* chemical observations that could provide a foundation for starting chemistry in secondary school" (ibid., p. 29) in accordance with criterion two, *relevance*. A discussion on "their ideas as to what constitutes the essential chemistry for living" (p. 29) led to a consensus that it was too difficult to achieve this, as it were, *a priori*. Instead the developers chose to adopt criterion three, *theme-led development of concepts*, trying to work out the essential chemistry for the course empirically, that is, *a posteriori*.

Finally, four groups were formed, consisting of two or three teachers each, with at least one teacher from secondary and one from tertiary education. These groups then chose from a prepared list either familiar material or a *theme* from everyday life which they wanted to work on; subsequently, they "spent some time working on a teaching scheme suitable for the *full ability* range within the age range 13-15" (p. 29). In Waddington's summarizing statement:

> What we wanted was to *try a test*, we accept it [the emphasis on science for life] – and *find out* what chemistry you taught" (G/W91:4).

Evaluation and decision

The initial aim which they set out to achieve in this first workshop – to develop, starting from their general design criteria, drafts of relevant teaching materials – appeared to be feasible; a first prototype became visible. Although they "got left with bits of paper which weren't very sensible", as Waddington put it, they also felt that:

> We got left with the idea that it was *possible*, it would be terribly difficult, it might not be acceptable for the most able children – but it was a jolly good idea *for the least able* (G/W91:4).

Since it seemed possible to develop, starting from everyday materials and themes, *fundamental* explanatory chemical concepts and principles (see section 4.3.2) which the *most able* pupils would need or want to know, they agreed that further work in this direction was "both necessary and worthwhile" (Garforth, 1983). There were quite a few "reservations, though, about the practicality of achieving widespread acceptance" (p. 30) from an examination board. And they saw, as the greatest danger, that a theme- or applications-led approach might be so *incoherent* "that pupils following such a course might be even more confused at the end than they are already, after following existing O-level and CSE courses" (p. 30). At the end of the weekend four possible channels for future activities were distinguished (p. 30).

A. Identify the chemical concepts and principles which are necessary in order to appreciate and understand the content of any proposed *new* chemistry course.

B. Write and collate material for teaching chemistry through familiar substances and themes to fit in alongside or replace parts of existing syllabuses.

C. Collect and collate existing Mode 3 syllabuses and examination papers with a view to disseminating information about "relevant" syllabuses nationally.

D. Write a new 16+ chemistry syllabus based on everyday materials and the applications of chemistry, carry out trials in schools, and persuade an examination board to pilot it.

The group of developers at York decided not to do channel A since they had found out that it was not possible to agree, *a priori*, on a formulation of "*the essential chemistry of living*". Nor did they try to identify the structure of chemical concepts and principles, customarily present in traditional school chemistry courses and usually thought necessary for any new school chemistry course to be considered a proper course that is also acceptable to an examination board. In brief, the group of developers at York did not perform a domain specific analysis of the nature and structure of the dominant school chemistry curriculum (condition one), an analysis which I have performed and reported on in Chapter 2.

Channel B was also not chosen, though it was a channel which had been pursued by Garforth and other teacher-developers before and has been pursued by groups of developers in many countries. The most famous in the UK at the time was probably the ASE project *Science and Technology in Schools* (SATIS, 1986), which produced a resource of about a hundred units of one or two lessons (requiring about 75 minutes) that function as enrichment or "add-on" materials to existing "science first" courses (Holman, 1987).

The developers at York began by exploring the feasibility of Channel C. They pursued this for a short time, until they decided, for a combination of practical and fundamental reasons explained below in the section *Crucial Moments* (4.4.3), to abandon this route in favor of large-scale development of a new chemistry course, that is, Channel D. As Garforth (1983) remarks:

> After much discussion it has been decided to attempt the most ambitious project, i.e. [channel] D!

Thus, by electing to pursue channel D, the developers hoped to find out empirically what would constitute a specific, *concrete teaching scheme* out of which would evolve a general, alternative syllabus and the chemistry involved in this. According to Francesca Garforth, "We didn't make any decisions about 'should' ... at the outset we were looking about 'did', *what did come out of it that was recognizably* chemistry" (G92b:9).

4.3.4 Conclusion

The most radical changes in the visionary curriculum of the Salters' Chemistry course compared to the traditionally realized O-level curriculum in England are visible in the *pedagogical* structures of these curricula. While the former is oriented towards the needs of all students, including the more able, and emphasizes thereby the needs of the less and moderately able students as future citizens, the latter is mainly oriented towards the needs of the future chemists, emphasizing thereby the needs of more able students. The visionary curriculum of Salters' Chemistry also favors the use of a bottom-up, applications-led approach to teaching chemistry, a teaching approach in which it is attempted to use laboratory activities related to daily life contexts as well as other practical activities taught by way of worksheets, against the theory-led and textbook-based approach of the traditional O-level curriculum. It is important to note that although the latter's intended curriculum did originally aim at student's understanding of chemical concepts, what it as a rule actually *realized,* was a kind of teaching to the test or to the exam, and a type of rote-learning. (See, for this point, the IF analysis in Chapter 2, leading to the concepts of Dominant School Chemistry and Normal Chemistry Education; the analysis in section 4.2.2 based on interviews with Francesca Garforth; and the analysis of Ziman (1980), all concurring in this conclusion.)

The major changes in the *philosophical* structure of these curricula are a change from a curriculum emphasis on *solid foundation of theory* (O-level) to a curriculum emphasizing applications of chemistry in daily life (Salters' Chemistry) together with an intended change in focus from explanation to exploration.

In line with the changes in the pedagogical and philosophical structures of the visionary curriculum of Salters' Chemistry, the *substantive* structure puts less emphasis on the development of the full set of abstract chemical concepts that is traditionally present. Basic chemical concepts are introduced in the context of daily life phenomena, and laboratory techniques are used with familiar materials. Therefore, in sum, the visionary curriculum of Salters' Chemistry departs in a radical way from the O-level curriculum in England, which is the representation of Dominant School Chemistry in England.

In subsequent sections, I will keep track of how this tentative vision of school chemistry, its structural components and design criteria, evolved in the ensuing transformations that first led to two stages of the written curriculum (sections 4.4 and 4.5) and to the formal curriculum of the Salters' GCSE Chemistry course (section 4.6).

4.4 The written and experienced curriculum of Salters Chemistry: The Year Three course

In this section I analyze the transformation of the visionary curriculum into the first stage of the written curriculum of Salters' Chemistry, the Year Three course. In particular, I will examine whether this transformation proceeds consistently with regard to the design criteria used. Firstly, I describe how the design criteria were applied in the case of the development of the teaching units which came to make up the Year Three course (4.4.1). Secondly, I describe the preparation and organization (4.4.2), the crucial moments (4.4.3), and the evaluation phase (4.4.4) of the developmental process. In the concluding section I show that the method for developing a 'relevant' school chemistry course (as described in section 4.3) evolved during the process of development, by analyzing the changes in design criteria. Finally, I will discuss, using my curriculum theoretical framework, the product of the developmental process, that is, the Year Three course, and establish whether it escapes from Dominant School Chemistry (4.4.5).

4.4.1 Application of design criteria to the Year Three course

The first workshop had shown the feasibility of developing drafts of teaching materials which could possibly lead to a 'relevant' chemistry course for all. Waddington felt:

> That it was then an act of faith, we thought we ought to try it again, but on a *bigger scale* (G/W91:4).

This in turn led to the application and modification of the three design criteria (section 4.3.4) with regard to the *specific and concrete* development of teaching materials for 13-14 year olds in the so-called Year Three course. Specifications of the general design criteria were at this point referred to as *tenets of faith*. Besides the decision "that we would do Year 3" (G/W91:5), it came to be stipulated, as a tenet of faith, that all participants in the development should work on "separate chemistry" (G/W,91:5). As Waddington (G/W91:5) explained:

> Secondly, we wanted to do it in chemistry. People who loved integrated science, whatever it was, had to sign on the dotted line they weren't going to start that controversy.[26]

Year Three "seemed the obvious one to go for" (G/W 91:5), although it was considered by many teachers as a difficult year.[27] Relatively little material had been developed for it, since it was a *transitional* year between the first two years of *general* science education and the last two years of externally examined (O-level) *separate* science education.[28]

> Most schools, even in those days, taught – I can't remember what it was called now – they took *combined* sciences the first two years of secondary school. Some schools continued to teach *combined* science, but a lot of schools taught *separate physics, chemistry and biology* the third year of secondary school and then at the end of that year they chose their GCE subjects or CSE subjects, their *advanced* subjects [see Fig. 4.1]. And this third year wasn't at *risk* from the point of view of *examinations* because it didn't matter too much what they had done because it wouldn't be basically part of the syllabus as long as we *covered some agreed elementary ideas*. And the first two years were out because they would be taught in so many different kinds of groupings (G/W91:5).

Thus, the developers realized that Year Three was still at "the point at which teachers were able to take on and use material that they enjoyed rather than follow an exact syllabus" (G92b:11). Furthermore, the *most able* students would not take part in the first trial because:

> We realized that no teacher in their right mind would subject O-level candidates to a highly experimental and very dubiously constructed course, *even if we could construct it* (G/W92b:10).

Apart from these more practical reasons, the decision of the developers, to limit themselves initially to the developing of teaching units for just one year, can be considered as a consequence of their view on curriculum development, namely, of their idea of finding out *empirically*, in pilot projects in a piecemeal way, what the design criteria would entail in a concrete case.

The first design criterion, *No preconceptions*, applied to this situation was considered by the developers to be the most important *tenet of faith*. In Garforth's formulation it became:

> You must *not* be influenced by your thoughts of what we always do with *the third year* or your thoughts of *what we must have covered* before we arrive in the fourth year (G/W91:6).

The second design criterion, *Relevance*, meant that teacher-developers should "start where young people are" (L92), and applied to Year Three this meant:

> That in these thirteen-year-old units that we were writing ... we would introduce things that were normally introduced in unfamiliar materials, using *familiar* materials (G92a:15).

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26 John Lazonby (L92) remarked that David Waddington was at that time particularly concerned about the small chemistry component in new or planned *balanced science* courses all over the world, courses which claimed to offer a balanced set of separate natural science courses. So, Waddington asked himself: "What, in all this, had chemistry to offer." See also Holman (1987, p. 435) who expresses a similar concern about school chemistry and "its future as a separate subject".

27 Nuffield Secondary Science (13-15), unlike Nuffield Combined Science (11-13), made a similar choice, that is, it also started in Year Three. See note 21 and the text there.

28 Campbell, et al. (1994, pp. 418, 423) mention the transitional nature of Year Three several times.

The third design criterion, *Theme-led development of concepts*, meant in this case that teacher-developers would start, in line with their experience with prototypical teaching materials gathered in the first workshop (see 4.3.2), from some selected areas: "Drinks", "Food", "Metals", "Clothing", or "Warmth", that is, to work on common areas which:

> "seemed to us to give the most comprehensive *coverage* of some agreed elementary chemical concepts and generalizations at this level" (G/W91:6).

For example, out of experiments on the theme of rusting would "gradually [come] the kind of generalized chemical concept of reaction" (G92a:15). For a detailed analysis of this theme or context of rusting, see Chapter 5.

4.4.2 Preparation and organization

The ambition of embarking on full-scale development along these lines led to a change, not only of the *scope* but also of the *nature* of the development process. As for the scope, producing teaching material for a one year course would require a lot of work. This also implied a greater amount of preparation by Francesca Garforth who was seconded therefore at this stage by John Lazonby, Malcolm Frazer, and David Waddington, who comprised the Salters' Chemistry Project Management.

Firstly, they tried to find out through consultations with teachers, what was the "lowest common denominator" (G/W91:5) of chemical concepts and experiments for pupils by the age of thirteen. This proved to be "almost nil" (G/W91:6). Secondly, they tried to find out what teachers could contribute, asking them to comment on "a list of about twenty global things" some of which had come out of the first workshop. They asked teachers: "Which [themes] do you think are the most fruitful" (G/W91:6), also requesting them to add one or two themes. Thirdly, they asked teachers which themes they thought they would like to work on. Fourthly, Waddington at this stage "took over organizing people at the workshops" (G92b:12), which included inviting "a representative of every level of education" (G/W91:13), and he took care of the urgent matter of finding necessary funds for the expanding project.

> We tried to have a mixture – teachers, industrialists, exam boards, inspectors. About thirty. We eventually got thirty. Writers – experienced writers, non-experienced writers ... young, old ... inner city, grammar, independent schools, comprehensive schools and so on. Most of whom stayed, the experienced writers, for example, we got John Holman and Graham Hill. So that group came. But in between I would think they probably had three or four bits of homework to do (G/W91:5).[29]

At this stage, Waddington felt that "we didn't want just *novices*, but we wanted people with a known track record of being able to write as well" (G92b:12). The next step was to ask invited participants of a Five-day Workshop to work in groups of three and, following the preparation and the homework, "to push them [the themes] around in terms

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[29] See also Campbell et al. (1994, p. 424): "The development process then centred around a series of intensive 4-day workshops which brought together a team of *experienced* school teachers from a wide range of types of schools (comprehensive, selective, maintained, independent, urban, rural), university-based science educators (with school teaching experience), school science advisors and industrialists."

of experience and so on" (G/W91:6). Finally, the Salters' Chemistry Management Team also invited "people of other developments, so we weren't seen in opposition" (L92).

In this way "we set up something that was counter to what the current fashion was" (G/W91:9). The current fashion in curriculum development in those days was: "The idea that "schools would be doing the curriculum development or [that] school things shouldn't be sent up" (G/W91:9). Examples are Garforth's initial efforts with developing materials for her CSE students, and her experiences with CSE teachers and their alternative CSE syllabuses (see 4.2.2).

In other words, there still was a widespread "anti-Nuffield feeling" as Waddington called it, which, the project management team in a way went against. At this point the *nature* of the Salters' Chemistry development process changed, from a "peripheral" model to a more or less "center-periphery model", a curriculum development model used in the 1960s and 1970s by, for example, the Nuffield programs in England and NSF programs in the USA.[30] But the Project Management Team did not use an extreme form of the center-periphery model. A great attempt was made to involve teachers not only in trialling the new units in the classroom, but also to involve many of them in the actual writing and developing process.

Thus, the Salters' Chemistry Project Management Team, based at York, began to lead a systematic effort to produce relevant curriculum materials for a one year transitional course along the lines of the previously agreed-on tenets of faith, or design criteria, and in collaboration with a carefully selected team of teacher-developers working on previously generated and selected themes or contexts. The resulting draft materials would be trialled first by teachers directly involved in the project and later disseminated to the periphery for further use in classrooms. Feedback of the trials would lead to revision of materials, subsequent trials, and the final editing process.

All this started in September 1983 with a Five Day Workshop held in York, during which the invited teacher-developers and other invited participants worked in groups of three or four on themes such as Drinks, Fuels, Metals, and Food. Plenary sessions would reinforce the tenets of faith or "catechism" (G/W91:4), so that everybody would be firmly committed as well as clear in their mind about what they would set out to achieve.

4.4.3 Crucial moments

The first crucial moment came very soon with the realization "that our marvelous preconception that all this work was available somewhere, and all we needed to do was point the teachers to it was hopeless" (G/W91:7). Instead, there appeared to be several reasons, practical as well as principal, to abandon Channel C, that is, the idea "to write teacher notes accessing them [the teachers] to materials that had already been published" (G/W91:5).

30 Campbell et al. (1994, p. 433) describe this as "a model for educational change in which a development team (the *center*) produces materials which are then disseminated to teachers (on the *periphery*). The Research, Development and Dissemination (RD & D) model is perhaps the best known such model".

> First of all, they wouldn't have the time to go and look things up; secondly, that they probably wouldn't have copies of these in the school library anyway, and thirdly, good as they were – and some of the experiments were very good indeed – *they didn't give us sufficient in the way of a teaching approach and that we would have to start writing from scratch* (G92a:5).

Furthermore, heads of department and beginning, as well as experienced teachers, all seemed to say to the development team that they would like to "actually have everything there to hand in the same booklet" (G92a). Under those circumstances it proved very hard for the teacher-developers *not* "to reinvent the wheel ... and we changed our plan of production at that point into full-scale workbooks" (G/W91:7), that is, they choose Channel D, as mentioned above in section 4.3.3.

The realization that they "were [now] doing something that was very different" (G92b:16) both with regard to scope (bigger scale) and nature of the development process (center-periphery) brought with it its own problems, the most important of which was:

> … the most worrying thought that everybody was worried about was that we were going to end up with a course which would be utterly and *totally confusing to both teacher and pupils* (G/W91:8).

More particularly, what had worried the developers since they first conceived of the possibility of an alternative, relevant chemistry course was how to achieve (Garforth, 1983, p. 30):

> A careful *integration* of the modules so that chemical concepts and principles evolved in *some recognisably sequential order* and that each was sufficiently *reinforced* in the course.

Whereas the starting point for the Year Three course could be chosen almost freely, since the baseline was for students about nil, the end point of Year Three was seen by the developers as being determined, at least partially, by the existing O-level content.

> We had to come out with *some kind of basis* for going on to do O-level, so when we got on to designing the course for Year 3, we had to bear in mind what pupils who had gone through a *standard* chemistry course would in fact have been exposed to, so at that point *external constraints* came in (G92b:10).

Thus, the problem for the teacher-developers now became: How to arrange a set of "appropriate chemical ideas" for 13-14 year olds, as introduced through selected contexts, into a *coherent* and what they called a "*recognisably sequential order*". Most of these "appropriate chemical ideas", they thought, were ideas such as "diffusion, solution, particle, molecule, atom or ... element and compound", chemical ideas which were considered "standard ... on any syllabus" (G92b:9).

Garforth realized that this procedure must sound "very anti-Salters" (G92a:5), in the sense that they were now obviously operating with a clear *preconception* of:

> Certain concepts which we all *recognized* we shouldn't leave out by the end of Year 3"(G92a:5).

In order to keep track of which concepts and experiments turned up in which lessons of the units organized around a theme, it was John Holman who proposed to have a "checklist" which evolved into lesson plans (blue sheets) and unit plans (green sheets). A lesson consisted of a double period of 70 – 80 minutes; a lesson plan would organize the set of activities which would lead pupils to understanding of a set of key points; a unit plan organized the 7-10 lessons of which a unit would consist; and the Year Three course would consist of four or five units. But, even more necessary, according to Garforth was to have the following device:

> But what was much more worrying was to have a *checklist* of what we had actually done [...] of the outcomes from everything in the *course* so that we could see that we weren't dealing with the same thing over and over again or that we weren't putting carts before horses […]. Or that we had actually got a logical basis, or a *fairly logical basis*, for something that turned up in another unit (G/W91:7).

It was Malcolm Frazer – "he was *Control*" (G/W91) – who took care of this, by starting to pin colored cards on boards on the wall. For instance, a green card for an "equation", or a white one for an "element" and other colored cards for concepts and for experiments. The functions of these course control or curriculum devices became to make sure that:

– nothing was done "more than once" (G92b:9);
– nothing was "missing" or "left out" (G92a:5);
– they had not done too much (G/W91:15);
– "people could see what was turning up in each unit so they could either work towards it or use the information that was turned up" (G/W91:8);
– reinforcement was taken care of as much as possible: that is, trying to develop chemical concepts in a progression of different levels of refinement, abstraction, and quantification after their initial simple and qualitative introduction.

Garforth remembered an interesting example, from the concomitant development process of the two Units, "Drinks" and "Clothing", of the first and, especially of the important fourth form of 'course control' (G92b:9).

> And then we tried *to match up* and make sure that we *didn't have it occurring more than once*, or if we got something like diffusion and we wanted the word 'particle' we had to make sure that 'particle' had occurred somewhere before. And when we got to "Clothing" we actually needed the word 'molecule', because we were dealing with large assemblages of atoms, so we had to go back and make sure that atom and molecule had occurred somewhere, so that was *put back* into "Drinks" as a sort of *refinement* of the word 'particle'.

In the process of working this way the developers came to the realization that they:

> Had to impose externally and by agreement a *sequence* of certain concepts (G92a:5).

Thus the developers made more and more explicit a design criterion which entails both a requirement for coverage and for a recognizably sequential order of elementary chemical ideas. This new design criterion did replace and goes, I think, directly against design criterion one, *No preconception*s, introduced in section 4.3.3. The latter admonishes developers to have no preconceptions about what should be in a chemistry course they are about to develop. So the design criterion now adopted sounds "very anti-Salters", as Garforth put it above.

Apparently, the developers felt they needed this design criterion for establishing some kind of *conceptual coherence* in order to avoid the feared confusion of both teachers and students. In this way they tried to solve their most worrying problem met during the development of a context-led chemistry course. After a few days of hard and intensive work – "several people were ... exhibiting battle fatigue" – came, in the eyes of the developers, the *most important crucial moment*. Waddington remembers the occasion as follows:

> And then about the third evening, or the fourth evening, there were dramatic moments when Malcolm [Frazer] spoke – he synthesized what was on his boards. He was a marvelous speaker. And this – it's remarkable, out of it suddenly *became sense* (G/W91:8).

At this point, the developers suddenly saw that a context-led development of chemical concepts could lead to a school chemistry course that was meaningful and worthwhile to the majority of students taking such a course as well as providing a coherent treatment of chemical concepts.

Besides the reinforcement of tenets of faith, and the ongoing process of checking the 'logical' basis of concepts, another function of the plenary meetings was "brainstorming" about ideas for themes or units: "each group was asked to explain itself at the plenary meeting in the evening" (G/W91:8). So, the units the teacher-developers worked on could be referred "back to the drawing board", and "there were several [units] that fell by the wayside" (G/W91:14,15), for instance at this stage a unit called "Shelter". By using the curriculum devices mentioned above, it could turn out that: the chemistry that came out of the units was not simple enough or just too much for that stage of learning (age and ability), or that the chemistry did not fit into the overall scheme of concepts used so far in the course units. Furthermore, the unit could not fit into the overall scheme of themes or contexts chosen so far. An example of an issue that came to be decided in a plenary session was the place and role of theory in the course. As Garforth recalls:

> ... and anything controversial like John Holman suddenly deciding that Drinks inevitably leading to kinetic theory, very simply. The Drinks people went rushing about the other groups and said, What do you think about kinetic theory? Do you think this is a good idea at this stage? And we had a plenary session to discuss kinetic theory (G/W91:8).

4.4.4 Experienced curriculum

In this section (and also in section 4.5.3), I will deal in a global way with the Salters Chemistry course as experienced by students in the classroom. In section 5.4, I will perform a detailed analysis of the experienced curriculum of the unit Metals, part of the Salters Science course.

Besides the 'internal' evaluation which took place during the ongoing development process including the plenary meetings, the first drafts of the Salters Chemistry units were also trialled in the classroom, that is, evaluated *externally* by feedback or comments from teachers and, initially, also through student responses.

Many teachers (about 1000!) reacted to Garforth's (1983) article in which the developers asked for help from teachers to trial newly developed relevant teaching materials, a confirmation of the readiness and willingness of teachers, alluded to in section 4.2.2. About 200 or 300 of these teachers – "those who were really interested in doing Year Three" (G/W91:11) – actually participated in the trials that started at the end of 1983 and went on the next year.

Their comments were on the whole favorable, although some were mixed with some concern about the level of understanding. As summarized by Garforth in one of the interviews:

> I've never known the children so motivated. It's amazing what stuck. Usually they go from one term to the next, without anything sticking from one term to the next, but this time it really seems to have sunk in what

> they did and they remember; and their practical skills have improved, and *they haven't reached the level of understanding that we would expect at the end of the third year*. But they've made up for that in what they have remembered: the *basics* that they've remembered and their *ability to think* and their *ability to physically manipulate* the material, so we think probably *it's worth it* (G92b:15).

On the other hand there were some teachers who remarked: "I can't think what the point of all this is, but the kids seem to like it" (G/W92b:15); and some teachers who felt that "it was pretty dull stuff and the fact that children were enjoying it really surprised them" (G92b:15).

Some children made "lovely comments", for example a pupil of a low ability group said:

> This is the best thing I have ever done since I came to school. We've been *using things I understood about* and not that stuff from the bottles on the shelf whose names I couldn't spell (G/W91:18).

Another pupil wrote: "I enjoyed this unit because it was dealing with *things I knew about* and not all those things with funny names we only see in the *chemistry laboratory*" (G92b:11). And one pupil simply said: "This is better than sulfur" (G/W91:18). These pupil responses seem to indicate that the developers were succeeding in one of their main aims, that is, "looking for *familiar materials* which would do things that in the *lab* we had used to do with something quite *unfamiliar* like *sodium or zinc*" (G92a:15). All units for Year Three were revised in the light of teacher comments and students responses. This kind of feedback along with the 'internal' evaluation led teacher-developers to the conviction that "we must continue ... knew we were off" (G/W91:8). Thus, the development of a one year course of relevant school chemistry, the desirability of which now was accepted by all parties concerned, seemed perfectly feasible. As pointed out above, *it made sense*.

Furthermore, there arose a quite unexpected, but favorable change in external circumstances which added considerably to the internal momentum gathered in the developmental process. This is summarized eloquently by Garforth:

> There was a lot of luck in the educational world at the time. So that the whole of the teaching of science had been thrown into the melting pot and the GCSE was on its way forward. Everybody had thought that it was going to die the death it had been dying since 1974 but quite suddenly it was on. And we knew that the *ground rules for the exam* were going to be totally different from the ground rules that had existed before. Students were going to be asked to show *what they could do*. *There was going to be a chance for a project and all kinds of things we wanted*, actually, to incorporate in our syllabus and we could see that our way, if we could get this third year over, we would have a clear run to Years Four and Five if we got it done in time. It was about the only time, I think, that there was *a window of opportunity* in secondary education where we could have got this through. We couldn't have done it at any other time (G/W91:9).

4.4.5 Conclusion and discussion

I will now try to answer the question, to what extent the transitional Year Three course captured "all kinds of things" the developers wanted, as formulated in their tentative vision and design criteria. In terms of my curriculum framework, this means whether the transformation of the visionary curriculum into the written curriculum of Salters' Chemistry was consistent with their proclaimed design criteria (see sections 4.1.3 and 4.3.3). I will do this in terms of changes in design criteria, focusing on the development process, and in terms of the curriculum structures introduced in Chapter 1 of this thesis:

the pedagogical, philosophical, and substantive structures, focusing thereby on the curriculum product (see Figure 4.5 below). This will also allow us to answer the question, to what extent the written curriculum of Salters' Chemistry, in the form of the Year Three course, did escape from Dominant School Chemistry as it existed in England at the time.

Design criteria

The most conspicuous change which occurred during the development process was the gradual replacement of design criterion one, *No preconception*s, by a conception referred to by the developers as a recognizably sequential order of elementary chemical ideas standard on any syllabus. At this point external constraints came in which would come to guide the development of teaching materials, the more so since a further development of the Year Three course would also have to address the needs of O-level candidates who were initially left out in the trial phase.

Design criterion two, *Relevance,* in the sense of starting from contexts taken from the daily life of students, could be applied in a largely consistent way. The choice of contexts at this stage was relatively free, as long as the contexts were fruitful with regard to the development of chemical concepts.

As noted above with regard to design criterion three, *Context-led development of concepts*, the design of the Year Three units were to some extent constrained by a standard list of chemical concepts and by a "recognizably sequential order" to be imposed on these concepts. Further, all but the first few units were further constrained by the extent to which previous concepts and the sequential order had already been introduced – only these first units could start as it were from scratch. The concepts introduced in later units had to fit in with whatever came earlier in terms of concepts and sequential order. This could lead to an imbalance with regard to the conceptual load the contexts of a unit had to carry.

Pedagogical structure

The developers had to bear in mind, as we saw, that the students they addressed had to make the transition from the first two years of general science education to the two years of an examination course in chemistry as a separate science subject. This meant that they had to comply with the, though not very strict, externally set constraints which had to be kept in mind in addition to their internally chosen design criteria that were part of the visionary curriculum of Salters' Chemistry. As became clear from their own evaluation of the trials, the Year Three units communicated to the less and moderately able students [Ped/A] some "worthwhile" learning experiences. These students not only enjoyed the course but also seemed to learn some basic concepts, and showed ability and confidence in thinking about and performing practical work [Ped/A]. Thus, the context-led teaching approach [Ped/TA], starting "bottom up" with familiar materials and applications, really seemed to further these students' appreciation of relevant chemistry, thereby also raising their chemical awareness as future citizens.

The pedagogical structure of the written curriculum of Salters' Chemistry, the first trial of the Year Three course, focused on the needs of the majority of students, on the less and moderately able students, aiming towards "chemical awareness for the future citizen" rather than on the academic preparation of future O-level candidates as potential future chemists. The development of a context-led teaching approach began to take shape, which together with the more customary lab experiments was used for the introduction and development of chemical concepts. At this stage the developers managed to escape to some extent from the pedagogical structure of Normal Chemistry Education (NCE), in other words, from the traditional O-level school chemistry in England.

Philosophical structure

The chosen curriculum emphasis on personal and societal relevance, using either familiar materials from the average home and kitchen or social, technical, and industrial applications, implies a different view or philosophy of chemistry. The central focus is not on theoretical or pure chemistry, but much more on practical or applied chemistry [Phil]. For instance, the focus is on "stuff that you could find around an average home" such as "pure cotton, pure wool, pure silk" (G92b:16), as against pure chemical substances such as potassium or pure water which you can find only in the laboratory.[31] The focus on familiar materials and chemical products, especially on the *purposes* for which these materials and products were used, and their properties in this regard, brought with it a greater emphasis on macroscopic properties [Phil]. The purpose or the use of things related to gross properties became more important for a relevant chemistry course than the relation of structure to atoms and molecules.

> We're more concerned with relating properties to use. In other words, we are moving up the macro level all the time, instead of down the micro level (G92a:15).

The Year Three course had to have, though, "a recognizable sequential order" (Garforth, 1983) and should introduce some agreed on chemical elementary ideas as a basis for the O-level examination course following the transitional Year Three course. This external constraint did not deter the developers from devising an applications-led chemistry course. After all, the Year Three course differed in important respects from the traditional provision for that year. By having to accommodate some agreed on basic chemical content, the resulting Year Three course probably deviated more from the visionary curriculum than originally envisioned by the developers.

The philosophical structure moved away from theoretical, microscopic chemistry and towards applied and macroscopic chemistry emphasizing relevance, purpose, and use. The developers did not escape fully from the philosophical structure of NCE, but they did try to look seriously for applications of chemical knowledge to familiar phenomena and materials, thus not using only 'academic' or laboratory applications as had been customary. They tried to use applications as starting points of units or lessons, not as afterthoughts or add-on materials.

Substantive structure

Although making *sense of familiar contexts*, by using only chemical concepts needed to make sense of these contexts (need-to-know), was the overriding aim, the developers came to feel that in order to achieve this aim it would be wrong "to throw away the baby with the bath water" (G92a:12). Hence, at least standard chemical techniques and experiments [Sub/CT] remained largely in the course, albeit applied to familiar materials

[31] See Chapter 1 for a discussion on the concepts of pure water (scientific context) versus tap water (technological context). *Pure* is used in pure cotton in a technological context; "pure cotton" is not a pure chemical substance here.

much more than to the usual laboratory chemicals. At first, the developers were still, as they said, "holding out against concept sets" (G92b:8). While developing the transitional Year Three course, though, they realized that a set of elementary chemical concepts [Sub/CC] had to be in the course, a set which should further have a fairly logical basis [Sub/CR].

Operating as they were within the common 16+ system (Figure 4.1), the objectives of the Year Three course had to be, they felt, on the one hand to enhance "chemical awareness for future citizens", and on the other hand, to lay a foundation for students who "were about to take O-level" chemistry (G92b:2). For the latter reason the Year Three units were called Foundation Units. While trying to establish a context-led teaching order by trial and error the developers had to, as they found out, impose externally and by agreement a *sequence* of certain concepts. The second design criterion, *relevance*, led them to emphasize as well as to *add* some chemical-societal or chemical-technological content about the making of familiar products and the *use* and *purpose* of these products as related to the *gross* properties.

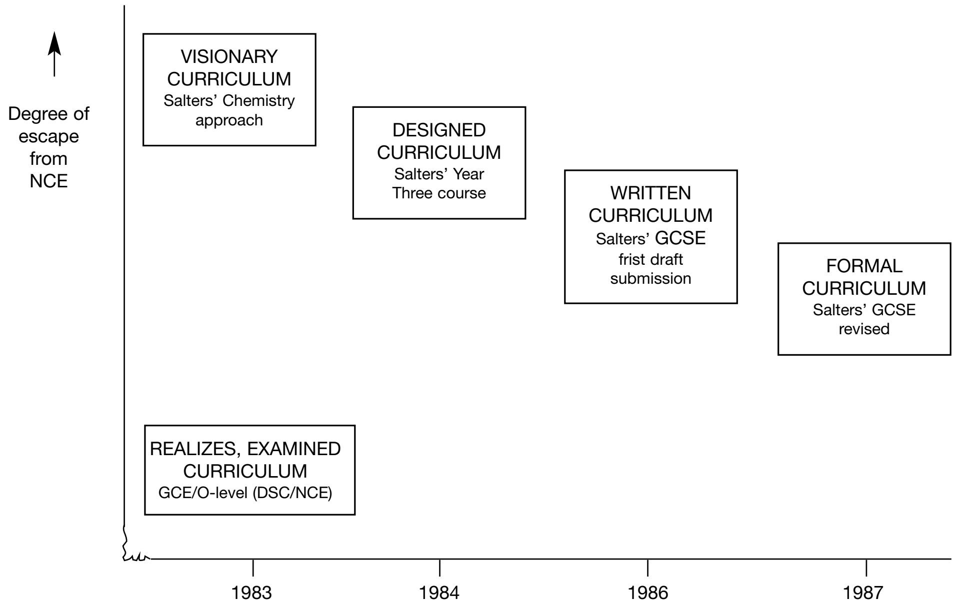
The substantive structure of the Year Three course shows, compared to a *traditional* Year Three course, some *reduced* chemical concept loading [Sub/CC]. For example, it avoids systematic chemical names for substances and reactions; on the other hand, it retains the same set of standard chemical techniques [Sub/CT]. The concepts were put in a "recognizable sequential order" (Garforth, 1983, p. 29) informed by "a fairly logical basis", although not in a top-down hierarchy, but bottom-up, that is, starting at the observational and manipulative level via low-level generalizations to more abstract relationships.

Thus, the developers did not fully escape from the substantive structure of NCE, nor from the philosophical and pedagogical structures of NCE. This partial escape has to do, I think, with both externally imposed and internally felt constraints, a point to be discussed further in section 4.7. There, the consistent use of all three design criteria, and the degree of escape of the written curriculum of Salters' Chemistry from NCE, will also be addressed in relation to the three conditions of escape listed in Figure 3.11. The discussion of the GCSE development of Salters' Chemistry, of the decisions taken and of the direction the development took, will make it possible to see the extent to which the chosen CTS curriculum emphasis of the Salters' Chemistry course, taken as a combination of a specific substantive, philosophical, and pedagogical structures, remained the same.

A schematic overview of the process of development over time is given in Figure 4.4 below. The box just above the baseline of the figure at the left marks the O-level curriculum, the representation of NCE in England in the 1980s. The boxes higher up the figure represent respectively: the visionary, designed, written, and formal curricula of the Salters' Chemistry course. The picture as a whole brings across the decreasing *degree of escape* in the process of development of an innovative course such as Salters' Chemistry, that is, in the process of matching the adopted vision and design criteria to the internal and external constraints met by the developers in designing a relevant, suitable, and feasible school chemistry course.

This is an illustration of an important curriculum phenomenon also described as "the *slippage* from any ideal formulation to what reaches the student" (Goodlad (1979, p. 64).

Figure 4.4 Process of development of the Salters' Chemistry course



The first box at the top left side of the Figure 4.4 represents the *visionary* curriculum of Salters' Chemistry as described and discussed in section 4.3. The distance between this box and the box put just above the baseline left, representing Dominant School Chemistry in England at the time, gives the maximum degree of escape.

The second box represents the *designed* curriculum, the first operationalization of the design criteria by the developers in a prototype, discussed in section 4.3. This phase was immediately followed by the development of teaching units for a *transitional* course in chemistry for 13-14 year olds, the Year Three course, as discussed in section 4.4.

The third box represents the next phase of the development, that is, the *written* curriculum, the extension of the designed curriculum realized by devising, elaborating, and revising prototypical teaching materials after trials or testing in the classroom by a group of developers. This phase consisted of the systematic development of a two year examination course in chemistry for 14-16 year olds, as discussed in section 4.5.

The last box represents the *formal* curriculum, that is, the formal acceptance of the GCSE Salters' Chemistry course for 13-16 year olds by an examination board.

In sections 4.3-4.6, I compare, in terms of my curriculum theoretical framework, the successive curriculum levels of the Salters' Chemistry project with the traditional 'academic' provision of school chemistry for 13-16 year olds as it existed in England at the time. Finally, I discuss the results of these comparisons, in particular, the *degree of escape* of the *visionary* Salters' Chemistry curriculum from Normal Chemistry Education (section 4.7).

4.5 The written and experienced curriculum of Salters Chemistry: The GCSE Course

In this section I will analyze the transformation of the visionary curriculum into the second stage of the written curriculum of Salters' Chemistry, the GCSE course, in particular whether this transformation proceeds consistently with regard to the design criteria used.

The decision of "extending to do Year Four and Five" (G/W91:10), that is, to provide relevant school chemistry for the 14-16 age group in the form and at the scale of a *national* examination course, had major consequences for the way the design criteria could be applied and the degree of professionalization and specialization of the management and development team.

Firstly, I will describe how the design criteria were applied in the case of the development of the first draft of the GCSE course (4.5.1). Secondly, I will describe those aspects of the preparation and organization process relevant for my analysis (4.5.2). Thirdly, I will analyze and discuss, in terms of my curriculum theoretical framework, the changes in design criteria and in curriculum structures during the development of the written curriculum, that is, the GCSE course, compared to the visionary curriculum.

4.5.1 Application of design criteria

In applying the first design criterion, *no preconceptions*, to the situation of developing an examination course and syllabus with national validation, the developers in York were to meet with further internal and external constraints. First of all, they now had: "a *baseline* ... the outcome of Year Three Salters'" (G/W91:14). Secondly, as the developers remarked,

> Then when GCSE became certain ... we had some very broad guidelines in the National Criteria for Chemistry as to what we would have to have in, if we were to be accepted as an exam course" (G/W91:15).

Thirdly, there was a danger, especially with an examination course: "by leaving something out that it would prejudice the child's opportunity to getting a grade at the other end" (G/W91:14). Thus, in this situation the developers were quite *explicitly* and *consciously* influenced by their *preconceptions* about what should be the beginning, the end, and the purpose of the course.

As for the second criterion, *relevance*, applied to this situation, this would entail that the themes for Years Four and Five had to be linked, at least to the ones already used in Year Three. Initially, these global themes "were a bit disparate and it was John Lazonby who came up with *links* ... a sort of *web*" (G/W91:14). This amounted to an ordering of the themes in terms of (i) survival, e.g., the units Food, Drinks, Warmth, Clothing; (ii) work and play, e.g., the units Metals, Buildings, Transporting Chemicals, and (iii) social relationships.[32] [33]

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[32] The 'web' had already proven its use for the five day workshop and had been based in part on the answers teachers had given to one of the questionnaires they had to fill in as homework.

[33] The latter theme was to be explored later in the Salters' Science materials for 11-13 year olds, in a unit called the "Salters Square" (L92). See also Lida de Gier (1992, p. 11).

The third criterion, *Context-led development of concept*s, when applied to this situation entailed that the set of themes or contexts for the examination course had to be matched to the particular "balance of theory, practicals, and relevance to social and economical problems" (G92a:8) as specified by the recent National Criteria for Chemistry. As a consequence, the generation and coupling of themes and topics was done by Garforth "the other way around this time; I asked for the topics; then myself tried to slot these into themes" (G/W91:14). Therefore,

> ... we had to be fairly *selective* about which topics we were going to use and how our topics were going to fit into themes. So, in a sense, I suppose, *we were going against our own philosophy* in that we had to have in our mind some idea of outcome even though it wasn't very specific. (G/W91:14)

Regarding the third design criterion, *context-led development of concepts*, the developers were, as they put it were also "going against our own philosophy". It was clear that the development of chemical concepts could, at this stage, no longer evolve from freely chosen themes or contexts, but had to take into account as an external constraint, the content requirements as specified by the National Criteria for Chemistry. Thus, on the one hand, the required chemical concepts were fairly fixed; on the other, the 'web of themes' grew tighter, too. Any newly suggested topic had to be fitted under two constraints: externally a set of a concepts, and internally a set of contexts, matched to each other in a coherent way. As Roberts (1982, p. 251) remarked:

> That is, the subject matter topics in a unit have to flow logically of course, *but so does the emphasis*.

Operating under these constraints, the application of the third criterion, *context-led development of concepts*, to the situation of the 14-16 age group, also meant that with these older pupils and with twice as much lesson time, "there might be more opportunities to put more *theory* into [the course]" (G/W91:14), a desideratum also required by the National Criteria of Chemistry. The latter criteria required the development of a relevant chemical course for the full-ability range, which again had consequences for the application of the third Salters' criterion, leading to an increased emphasis for *all* students on *explanations* in terms of *abstract* chemical concepts and principles compared to the visionary curriculum of Salters' Chemistry.

During the workshops for the GCSE development there evolved and was articulated *a new, fourth criterion*.[34] In addition to the teaching strategy which tried to use optimally the standard set of chemical experiments and techniques but with familiar materials and contexts, the developers now consciously "were trying to introduce as *many different [teaching] strategies* as possible" (G92b:15). This then led to learning activities which came to include, for example, "making a poster, or doing a survey ... tabulating data, role play" (G92b:15) and other forms of *practical* learning activities, including group discussion, which were all sandwiched, as it were, with the conventional laboratory

[34] In Campbell et al. (1994, p. 419), the developers describe, *in retrospect*, this criterion as: "The course should include a *wide range of activities* in which students can actively engage". It is seen there as one of two design criteria of the Salters' approach while the first one (p. 418) mentioned there consists of a combination of what I call criterion three, *context-led development of concepts*, and criterion two, *relevance*. Criterion one, *no preconceptions*, is only mentioned in passing (p. 423) there, but see Lazonby, et al. (1992, p. 899) for a more explicit reference, saying: "Many curricula are devised by defining what is expected of students at the end of the course. We deliberately closed our minds to this ..."

experiments between the set of leading themes or contexts and the set of chemical concepts to be developed. Teacher-developers could thus devise an array of learning activities which would link in the best possible way required concepts to set contexts.

4.5.2 Preparation and organization

Teacher-developers were asked first to come up with topics but within a previously, more or less, agreed-on set of themes, and subsequently to think about "*suitable* topics within these themes", trying to answer the question "which of these [topics] do you think is going to produce some *worthwhile* chemistry?" (G92a:12). Worthwhile chemistry was conceived as the product of teaching and learning chemistry in accordance with the Salters' design criteria emphasizing for students "that you can *do* things and *understand* " (G92a:11).[35]

Writing and developing twice as much material, for the years Four and Five, for an examination course brought with it some further specialization of tasks. About the same management and writers team which had devised the Year Three course, started to develop another ten units needed for the GCSE course on the basis of the design criteria and within the external constraints mentioned above.

But a number of other tasks had to be attended to as well. Thus, Waddington went looking for an examination board which would accept the Salters' Chemistry course, while Garforth took care of writing the required GCSE syllabus. Peter Nicolson, initially one of the teacher-developers, joined the management as a full-time liaison officer between the development center in York (UYSEG) and the teachers in the field. Graham Hill and Susan Adamson, initially also teacher-developers, became full time editors for the project, and were in charge of editing the final version of the course; Susan Adamson also was to write the *"The Salters Chemistry Course: An Overall Guide to Teachers"* (UYSEG 1988). Finally, David Waddington together with Graham Hill, John Holman, John Lazonby, and John Raffan wrote a so-called *student* book supporting the Salters' Chemistry course. I will now discuss a few points concerning these tasks which are relevant for my analysis of the Salters' Chemistry curriculum.

Examination board

The first examination board they approached, David Waddington recalls, "criticized us for trying to do what we were doing" (G/W91:10), in particular for their choice of a center-periphery curriculum model. John Raffan then suggested to approach the Oxford and Cambridge Schools and Examination Board, part of the Midland Examining Group (MEG). The officer of that examination board eventually did accept the Salters' proposal quite easily and also offered, even more to their surprise, a substantial amount of money for development costs. Because, as explained later: "John (Raffan) said it is a good thing, and I trust John (G/W91:10)." Waddington and Garforth remarked on episodes like this (G/W91:9):

> A lot of *lucky* things happened at that moment that allowed us to continue; you use your luck.

[35] This intriguing notion of worthwhile chemistry is also mentioned in the Overall Guide for Teachers where it says: "Of course, only those topics which turned out to provide a natural introduction to some "worthwhile chemistry" were developed" (OGT, p. 9, emphasis theirs).

Writing, trialling, editing and teacher guide

The actual writing process of GCSE units was organized in roughly the same way as that of the Year Three units. On the full course trials, starting September 1985, they received "progress reports and comments" (OGT, p. 79) from teachers. About twenty teachers were involved in 1985 and up to a hundred in 1986. Direct feedback from students in the form of written comments was not sought as it was in the design of the Year Three course (see section 4.4.4).

The GCSE course, to a much greater extent than the Year Three course, had to have as they put it a "recognisably sequential order", since it had to be developed under more constricting external constraints with regard to both content and coherence of concepts, over and above the internally led selection, sequence, and coherence of contexts. The curriculum devices mentioned earlier, the lesson plans, the overall plan of the unit, and the 'web' of contexts, were used to that effect, as was a "checklist of the outcomes from everything in a course" (G/W91.7), that is, the overall plan of the course.

The Salters' Chemistry course (OGT, 1988) further explained in some detail the teaching objectives, the philosophy, and structure of the course, including the development of chemical concepts in relation to the selected contexts and practical activities used to introduce them.

At the end of the development process Susan Adamson had "a more detailed look, an overall look at the development of concepts" (G/W91:15), the result of which was included in the Overall Teacher Guide (pp. 22-30). As a consequence, the editing of the final version came to involve not only leaving some things out but also "quite a lot of rewriting and new lessons and links" in order to increase the coherence of the course (G/W91:16). They "polished it up enormously while adding headings such as SIS and SAG" (G/W91:16), which stood for "Student Information Sheets" and "Student Activity Guides" and were pages of the units to be handed out to students.

They also reorganized and actually changed parts of the course, "sometimes a whole unit" (L92). Thus, in the editing process of the final version, more complete and explicit than during the developmental process, the editors "were analysing what there was, using what we perceive, what we *all* perceive to be *the structure of chemistry*" (L 92). In retrospect the developers stated:

> "Clearly though, there is implicit in this approach *a need*, at the editorial stage, to review the progression and "spiralling" of ideas within the course *to ensure coherence* in the treatment of the *major scientific concepts and ideas*" (Campbell et al., 1994, p. 423).

Syllabus

Garforth said, "our syllabus was going to be, in true Salters' fashion, to be derived from our units" (G/W91:14). The central principle that came to structure the units of the course, context- and activities-based teaching of chemical concepts, a sort of amalgam of the four design criteria, implied that chemical concepts would have to be introduced as it was called, on a *need-to-know* basis, that is, as they arose 'naturally' from the selected contexts. By the same token, it implied that chemical concepts which would *not* be needed to make sense of contexts and activities would not have to be dealt with in the units, and as a consequence also not in the syllabus.

The *draft* syllabus written with this idea in mind was presented in June 1986 to the School Examinations and Assessment Council (SEAC), which was "very sympathetic towards the syllabus" (G92a:9). Because the Salters' syllabus showed some *reduced* concept loading (Smith, 1988) it had to be revised if the developers wanted it to be accepted "as an examination with the full range of grades on the Mode 1" (G92a:9).[36] The syllabus did not deal substantially with a number of chemical concepts: some families of elements (halogens, alkali metals, and alkaline earths), the periodic system, atomic structure and bonding, some equations, and some quantitative chemistry, e.g. the mole concept.[37] This was, as noted above, an important consequence of the educational philosophy and method of development of Salters' Chemistry, that is, these chemical concepts did turn out *not to be needed* to make sense of the selected contexts. At the second presentation, after having accommodated their syllabus to SEAC's requirements – "we did insert a bit more" (G92a:9) – they were again criticized for not having some (other) chemical concepts in their syllabus (heterogeneous catalysis, equilibrium, and some equations) but this time they were "saved by an industrialist" (G/W91:12) on the SEAC committee.[38] It is worth recounting this "lucky" episode in full.

> When it came to the Salters' one [i.e., the syllabus], the chairman who is an *academic chemist* was terribly dubious, the HMI [inspector] was mildly enthusiastic; the *teachers* were very suspicious. And it was touch and go. The *industrialist* got to his feet and said, "You've given me I don't know how many syllabuses and exam papers to read. They have all looked utterly boring. *They all look just like what I did when I was a boy at school.* This is the only one that appears to pay more than lip service to the government's request that you should be more *oriented to the chemical industry and its products*. And I recommend that this go through ... if it doesn't I shall leave this committee." (G/W91:13).

And the chairman, quite taken aback, had to draw the conclusion that, "I suppose, yes, well, perhaps it's a good idea" (G/W91:13). And so it happened, that the Salters' Chemistry syllabus became but for "some minor alterations" (G/W91:12), in June 1987, the first nationally validated "relevant" GCSE syllabus, aiming at chemical awareness for the future citizen.

Examination papers

John Lazonby and David Edwards were writing the examination papers which "really were new" (G/W91:13), in the sense that the questions asked reflected the education philosophy of the Salters' approach as much as possible by stretching the "slim-line" constraints set by the National Criteria of Chemistry. The Midland Examination Group also "supplied welcome assistance in developing the assessment model for the GCSE syllabus" (OGT, p. 6). Furthermore, the developers were able to make full use of the marks (min. 15%) "for our examination for the industrial and social applications of chemistry" (G92a:14). As they said, "we could go up to 20%" (G92b:17) which was more

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36 This *empirical* outcome was consistent with their thinking at the time, as can be gauged from the contribution to the Royal Society report of Garforth, Lazonby, and Waddington, titled, "A reduced-content 16+ syllabus in chemistry".

37 See Smith (1988) where these concepts are identified in the context of a critical appraisal of the content of GCSE science courses and their assessment schemes at the time, including traditional O-level and Nuffield as well as Salters' Chemistry courses. See Lazonby et al. (1985) for a discussion of difficulties the introduction of the mole concept met in traditional and Nuffield courses. Campbell et al. (1994, p. 427) give as a reason for not including the mole concept in the Salters' Chemistry course: "The mole concept does not emerge, from the design criteria, as essential for understanding at this level".

38 It was "government ruling", in agreement with the greater demand for social, economical, and industrial relevance as expressed by the National Criteria (*ca.* 15% of the exam), that every SEAC committee had to have an industrialist on it.

than any other course had at that time.[39] Peter Nicolson looked after the scheme for teacher assessed marks.

Teacher training

As a liaison officer, Peter Nicolson was also in charge of the teacher training, which initially comprised sessions with small groups, but which later in 1986 and 1987 evolved into "massive training sessions of teachers" (G92b:14). The latter, called Salters' Users Workshops or Conferences, organized by UYSEG, took as much as four days and involved up to 150 teachers.

Teachers received an introduction to the Salters' approach and examples of the teaching materials developed on the basis of the main Salters' design criteria, relevance and context-led development. Subsequently, teachers working in small groups gained practical experience with the development of a prototype, starting from a relevant chemical context. In plenary sessions the drafts of the teaching materials were discussed. Thus, teachers had a chance to experience and reflect on the Salters' approach in action. These activities were intended to reinforce their understanding of the Salters' approach, and to contribute thereby to a proper use of the Salters' Science course in the classroom.

The conferences were funded by the Salters' Company, which had been persuaded by David Waddington who argued that a theme-based or context-led approach such as that taken by Salters' Chemistry would have "a bigger impact on chemical education" (G/W91:11) than the customary public school-oriented funding. Garforth said that "they didn't skimp" (G92b:14) on teacher training, as they had done on collecting feedback from pupils, due to time pressure.

> I think that was one of the best things about the course ... that teachers who were thinking of taking it up or who had said they wanted to take it up were invited to these courses at York. (G92a:11).

Thus, over the years many teachers were invited to York and became acquainted with the context- and activity-led materials developed, that is, with the Salters' approach. At teacher workshops they also acquired "the experience of a lot of practical work they hadn't done before" (G92b:11), including non-traditional practical activities such as role-play and group work. As a result of the Salters' Users Workshops many teachers decided to adopt the course for their schools.

Student Book

The course was initially conceived, designed, trialled, revised, and edited in the form of sixteen teacher units. Each unit consisted of a unit plan, lesson plans and teacher notes, and of easy, removable, worksheets for students, that is, student information sheets (SIS) and student activity guides (SAG). Waddington explained:

> Then came this awful thing. We hadn't got a textbook. We didn't *want* a textbook. I suppose in the end it was, in part, a commercial decision. That if we didn't write a textbook for it, somebody else would, and they wouldn't write it as well, and anyway why not get some money back into the project by writing a textbook (G/W91:16).

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[39] See Smith (1988, p. 112) for data which support this conclusion.

This led in 1987 to the organization of the writing of a so-called *Student Book* which would fulfill a number of functions of a regular textbook: "To excite children, and to do homework, and to tell stories, and to revise" (G/W91:16). It was not a traditional textbook, since it had only a supplementary function for students who followed the course. In effect, the course was essentially carried by the sixteen teacher units, that is, for the students, by its worksheets. The student book was "very carefully written with the Salters' ideals in mind" (G92a:12) by the four most experienced authors who had actually written textbooks before, namely Graham Hill, John Holman, John Lazonby and John Raffan, with David Waddington acting as editor. It was this student book, *Chemistry, The Salters' Approach* (1989), that the authors dedicated to Francesca Garforth for her inspiration.

4.5.3 Experienced curriculum

The Salters' GCSE syllabus was officially and nationally validated by SEAC for the "full range of grades on Mode 1" (G92a:9), which made the course in principle suitable for the full ability range. The teaching units, which had given rise to the syllabus, had been revised and edited on the basis of teachers' comments that also signaled the need for an *overall* teaching guide.[40]

Just from the numbers (about 100) of schools or teachers who trialled the course, and from the much greater number (250 – 400) who took it up after the trial phase as an exam course for their GCSE students, it became evident that the Salters' Chemistry course solved the problems of these teachers. As the developers put it, the Salters' Chemistry course, and later the Salters' Science courses, were "a *solution* to the user's *problem*" (Campbell et al., 1994, p. 429):

> The extent of uptake will, therefore, depend on how well the developers have identified the current "problems" facing potential users, and whether their "solutions" are perceived as such by enough potential users.

Apparently many teachers felt they needed to do something different for their wider range of students, partly for principled reasons as had been the case with the pioneering CSE teachers (section 4.3.2) and partly for practical reasons with the national GCSE coming up. Thus, teachers felt a need to provide a course which would work also for their less able pupils, since many of them did not have any experience with less able students in the former O/CSE system (Figure 4.1).

In the GCSE system the course had to be appropriate for the full ability range, for both the less able and the more able students. So, the slogan 'Science for All' meant here *one science course for all students*. The Salters' Chemistry course seemed to fulfill this dual need to the satisfaction of teachers, and also indirectly, one could say, to the satisfaction of pupils. Although initially the developers had expected "about 500

[40] See (Campbell et al., 1994, pp. 440-444) for more details on other forms of course evaluation.

candidates the first year", they got "up to 8000" in 1988, and "it peaked about 12000 – 15000" (G/W91:13) in 1990.[41]

It also became clear that the Salters' Chemistry GCSE course was suitable for the *full* ability range, that is, not only for the less and moderately able, as they had thought initially, but also for the *most able* children.

> Then when we actually got children from independent schools, children of really *high ability* doing it, we were *amazed*. The exam board had been perfectly prepared not only to accept the low numbers but also they would, in the first instance, be children of *lower ability*. Schools would enter their brighter pupils for traditional syllabuses and they would enter their less able for the Salters' syllabus. But we got a lot of schools, particularly girls' schools, who entered *the whole lot* for Salters' (G/W91:19).

While they were amazed about this, Waddington probably also felt relieved. Not only did the ground rules of the GCSE system require them to produce a chemistry course, appropriate for the full ability range including the most able students, but as Waddington remarked later:

> It was paramount that the course should also be, and be seen to be, appropriate for those students who had traditionally excelled in chemistry" (W97).

4.5.4 Conclusion and Discussion

As with the Year Three course, I will now try to answer the question, to what extent the GCSE course captured "all kinds of things" the developers wanted as formulated in their tentative vision and design criteria (see sections 4.1.3 and 4.3.3). In terms of my curriculum framework, whether the transformation of the visionary curriculum into the written curriculum of Salters' Chemistry, now in the form of the GCSE course, was consistent with their proclaimed design criteria.

Again I will do this in terms of changes in the design criteria, focusing on the development process, and in terms of the curriculum structures introduced in Chapter 1 of this thesis: the pedagogical, philosophical and substantive structures, focusing thereby on the curriculum product (see Figure 4.5 below). This will also allow us to answer the question, to what degree did the written curriculum of Salters' Chemistry in the form of the GCSE course escape from Normal Chemistry Education, that is, from traditional O-level chemistry, in England.

Changes in design criteria

Following is a brief discussion of the changes in design criteria that resulted from their application to the situation of developing the GCSE exam course (see section 4.5.1).

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[41] According to the Salters' Chemistry Overall Teaching Guide (1988, p. 6), "10,563 candidates took the first GCSE examination in Chemistry (Salters') in June 1988". The arrival of the National Curriculum, from 1989 onwards, which made balanced science (a combination of physical sciences, including chemistry and biology) mandatory led to a steady decrease from 1990 onwards in students taking separate chemistry courses, including, with some delay, Salters' Chemistry.

First, design criterion one, *No preconceptions*, has now been replaced by "what we perceive, what we *all* perceive to be *the structure of chemistry*" (L 92) in order to arrive at what was called some worthwhile chemistry. It is to be noted that the developers did not make explicit in detail, what they meant by-"*the structure of chemistry"* – and which Garforth (1983, p. 30) referred to as "a corpus of knowledge without which no syllabus could be called chemistry" (section 4.3.1). That is, the developers did not try to fulfill condition one: *Perform a domain specific analysis of the nature and structure of the dominant school chemistry curriculum* (see also sections 1.2.2 & 2.3.2, and Figure 3.10).

The application of design criterion two, *Relevance,* initially leading to a free choice of contexts, now led to a choice of contexts constrained by two factors: taking into account what the developers viewed as a "web of contexts", and matching these contexts with the topics as required by the National Criteria for Chemistry.

The application of design criterion three, *Context-led development of chemical concepts,* changed more and more from a strictly context-led development to a *conceptually* led development of chemical concepts, guided by the joint constraints of "*the structure of chemistry*" and the National Criteria for Chemistry. At the second editorial stage at the end of the GCSE trial this led to a reordering of chemical concepts in order to increase the conceptual coherence of the course. For example, the last unit of the Salters' Chemistry course *had* to deal with a number of concepts about chemical bonding not yet addressed in previous units. This resulted in a unit with a somewhat uneven conceptual loading compared to previous units. The unit was subsequently provided with the theme or label, "Burning and Bonding".

Finally, during the development process of the GCSE course a fourth design criterion evolved: stressing the use of a variety of learning and teaching activities.

To sum up, the curriculum emphasis of the Salters' Chemistry GCSE course changed from an intended school chemistry course with the emphases *Everyday Applications* and *Science, Technology, Decision* to an course which tried to combine these two emphases with what Roberts (1988) called a Solid Foundation emphasis. As we will show in detail in Chapter 5, this shift in emphases had as a consequence, that the ratio between CTS content and PC content (Aikenhead, 1994) used in a unit must change accordingly.

Changes in curriculum structure

The most important components of the pedagogical, philosophical, and substantive structures of the written curriculum of the Salters' Chemistry GCSE course are categorized in the right-hand column of Figure 4.5. For purposes of comparison, the left-hand column gives the corresponding components of the written curriculum of Salters' Chemistry for the Year Three course. The most prominent changes have been italicized.

To sum up, there emerges here a trend towards a stronger emphasis on the needs of the more able students corresponding to a stronger emphasis on chemical theory and corpuscular explanation, largely set within a traditional structure of school chemistry as perceived by the developers.

Figure 4.5 Shifting curriculum emphasis in the Salters Chemistry development [a]

Curriculum categories	Written curriculum: Year Three course	Written curriculum: GCSE exam course
PEDAGOGICAL STRUCTURE	**ESSENTIAL CHEMISTRY FOR LIVING**	**CHEMICAL AWARENESS AND BASIS FOR FURTHER STUDY OF CHEMISTRY**
Aims	Chemical awareness future citizens; Making sense: internally set aims; CSE/GCE transition (external constraint).	Chemical relevance, making sense; Internally and externally set aims; *Full ability range, including most able.*
Teaching approach	Bottom-up; Central role of relevant experiments; Familiar materials- and theme-based; *No textbook*, only teaching units.	Bottom-up; Wide range of activities; Context- and applications-led; Teaching units and student book (add-on).
Learning approach	Accessibility of level of knowledge; Interest and motivation (worksheets).	Interest and motivation (worksheets).
PHILOSOPHICAL STRUCTURE	**RELEVANCE AND USE**	**RELEVANCE AND USE**
Foundations of Science	Daily life phenomena/applications; Theory on "need-to-know" basis; Most able need or want more theory.	*Theory on "need-to know" basis: most able need or want more theory and abstract explanation for next level (A-level).*
Methodology of Science	Communal problem solving activity, including social, economic oriented problems.	Communal problem solving activity, including social, economic oriented problems.
Foundations Chemistry	Applied chemistry: internally set emphasis; Purpose/use related to gross properties; More macrolevel than microlevel.	Applied chemistry; Internally and externally set emphasis: industrial/product oriented; *More central role of corpuscular theory.*
Methodology of chemistry	Making things; Analyzing things made.	Making things; Analyzing things made.
SUBSTANTIVE STRUCTURE	**"A RECOGNISABLE SEQUENTIAL ORDER"**	***"STRUCTURE OF CHEMISTRY AS WE PERCEIVE IT"***
Chemical Concepts	Some agreed elementary ideas.	*Some reduced conceptual loading, e.g. not the mole/some equations.*
Chemical Relationships	Some kind of basis for O-level; Standard on any syllabus.	*As much as needed by familiar contexts, e.g. not periodic system, atomic structure.*
Chemical Techniques	Lab techniques applied to familiar materials.	Standard but applied to familiar materials.

[a] Most keywords are drawn from interviews and publication developers; some paraphrasing added.

4.6 The formal curriculum: the GCSE exam course

In this section I will analyze whether the transformation of the visionary curriculum into the formal curriculum of Salters' Chemistry proceeded in a consistent way. The Salters' Chemistry GCSE examination course, taken as the end product of the developmental process, was published as a set of curriculum materials in 1987, with its first examination in 1988. As we saw, the project was not originally conceived as it turned out, nor did it follow-a fully predetermined plan. The developers stated:

> Rather, the work *evolved* from more *humble* aspirations and more *circumscribed* ambitions. Step-by-step extensions led from an original 1 year course in chemistry, for 14 year olds, to a 3 year chemistry programme and a national examination, the General Certificate of Secondary Education (GCSE), taken by 16 year olds at the end of year 11 (grade 10) of their schooling (Campbell et al, 1994, p. 416).

The very first "humble aspirations" originated with Francesca Garforth in the early 1980s. In section 4.2.2, I have described the circumstances and experiences from which her vision of a new and relevant school chemistry course evolved. The curriculum emphasis arrived at was described as:

> A chemistry syllabus based on everyday materials with *chemical awareness for future citizens* as a principal aim (Garforth, 1983).

Up to now, I have described and discussed the development of the visionary and designed curriculum (section 4.3), which evolved into two stages of the written curriculum of Salters' Chemistry: Year Three in section 4.4 and the GCSE course in section 4.5.

In this section of Chapter 4, I describe, analyze, and discuss the formal curriculum. Again, I describe and analyze in terms of my curriculum theoretical framework the application of the design criteria and its changes (4.6.1) and the resulting curriculum structures during the development of the formal curriculum, that is, the GCSE exam course (4.6.2), followed by a discussion of these changes, and the degree of escape from NCE in section 4.6.3. For an overview of the developmental process, see Figure 4.4.

4.6.1 Application of design criteria

In June 1988, more than 10,000 candidates took the GCSE exam as specified by *Chemistry (Salters') Syllabus Code 1377* (hereafter referred to as SLB). About 75% of the students passed with grade A – D. This constituted the successful realization of a "remarkable curriculum development which has been driven by the ideas and enthusiasm of the teachers involved", as it said in the *Overall Guide for Teachers* (first edition 1988; hereafter referred to as OGT). This teacher's guide contained the "overall strategies for introducing and managing the course which supplemented the tactical support [given by] the sixteen unit guides [revised edition 1987] which make up the main body of the course" (OGT, p. 1). A second supplement, a Student Book introduced for student support, *Chemistry: The Salters' Approach*, was published in 1989. These curriculum products make up the formal curriculum of Salters' Chemistry course.

The writing of a national syllabus implied, of course, that the course content, as it had evolved during the developmental process had to be *matched* as a whole to the National Criteria of Chemistry, a set of broad guidelines in force from 1985 onwards. Garforth:

> You start with one set of ideas, like Nuffield did, but you've got an exam at the other end, so somewhere you've got to *match*" (G92b:8).

The National Criteria were taken by the developers at this stage, as something to which one had to adapt in the end, so the criteria were not perceived as being very prescriptive. Once the National Criteria for 16+ chemistry were officially accepted, the developers tried to match the criteria, but to do so as much as possible in line with their intentions.[42] This meant that, "the *core content* required by the National Criteria of Chemistry is *covered* in the syllabus" (SLB, p.1).

Although "the syllabus does not constitute a teaching sequence and should be read in conjunction with the course materials" (SLB, p. 8), the overall guide for teachers notes:

> In some cases the logical development of concepts does dictate a teaching sequence and this is noted in the recommendations (OGT, pp. 22-24).[43]

This implies that in other cases developers and/or teachers had complete freedom to follow a sequence of concepts, for instance as it emerged from chosen contexts and/or activities.

It is noteworthy that in neither the Salters' Syllabus nor in the Overall Guide for Teachers is there a reference to the first design criterion, *No preconceptions*, while the other three design criteria are explicitly mentioned.[44] As we saw above, design criterion one did receive primary and explicit emphasis during the development of the visionary and designed curriculum, but it received less attention during the stages of the written curriculum of the Salters' Chemistry project. During the developmental process it was gradually realized by the developers that they had to conform to some extent to what they called, "a recognizably sequential order" of elementary chemical ideas, thereby replacing, albeit with a rather bad conscience, design criterion one, *no preconceptions* (section 4.4.3). The first design criterion, one could argue, is most relevant for developers, but not for teachers executing the curriculum or for administrators, that is, the very audience addressed in these documents (SLB and OGT) here. On the other hand, as it says in the introduction of the unit Metals (1989), design criterion one could well be relevant for teachers.

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42 Many chemistry teachers had tried to influence the contents of the Draft National Criteria for 16+ Chemistry, by taking part, either individually or collectively, in "an exercise in *teacher consultation* never before undertaken" (Garforth, 1982a). Some of their comments, for example, those of the Education Division of the RSC (with Garforth as a member) "were considered by the working party when formulating the draft National Criteria for 16+ chemistry" which was published in January 1982 (Garforth, 1982b). See also Harding (1986, p. 49).

43 As quoted above (section 1.2.2), a strikingly similar recommendation comes from a Dutch chemistry syllabus. There it said that: " Although it is true that a syllabus presents the topics in an order which is as *logical* as possible, this does not mean that the topics of a course in a certain year have to be taught in that *order*. The teacher is free to choose an order, though often *the structure of the subject* makes it necessary to teach certain topics before others." (Min. O&W, 1984b). My analysis and research of the *structure of school chemistry*, as reported on in Chapter 2, resulted in a description of Dominant School Chemistry as a form of Normal Chemistry Education, exemplified by the 'core content required by the National Criteria of Chemistry' referred to by the Salters' developers above.

44 Holman (1987, p. 435), looking back on the design of the course units, does refer to the first design criterion as follows: "True to the philosophy of 'applications first' they [the units] were created by reference to everyday themes, *not to preconceptions about what should be taught in a chemistry syllabus*".

> "who want to introduce replacements and modifications to parts of lessons, whole lessons or *even whole units* where they feel it is appropriate".

As for the second criterion, *relevance*, this is expressed in the syllabus as follows:

> Each part of the course starts with a *material or phenomenon* with which most students can be expected to be *familiar* [Sub] as a result of their own experience or through the media of books, papers and television. The behaviour of such materials, their *use related to their behaviour* [FC] and their importance in our lives are studied through student activities ... (SLB, p. 1)

> Each topic should have its origin in *everyday* experience and be developed through the use of *familiar substances* [Sub] (OGT, p. 9).

The syllabus gives an elaboration of the "*fundamental* emphasis" (SLB, p. 8) of the Salters' Chemistry course as, what I called in section 4.1.2, a C*hemistry through Technology* (CTS) course. The relevance of chemistry in the real world is addressed by presenting "the syllabus *content* under the headings of eight *unifying themes* which run throughout the course" (SLB, p. 8). These themes are: Natural Resources, Food and Water, Fuels and Energy, Useful Materials, Health, The Environment, Corrosion and Erosion, and Industrial Processes.

These unifying themes support, as it is put, the "amplification of content" (SLB, pp. 9-13) in terms of sub-themes, contexts, and applications which are to be matched to the "Chemical Content and Concepts Developed" in the course units (SLB, Section A: 9-14).

In Chapter 5, I will give a detailed analysis of the theme Corrosion as treated in the unit "Metals" in relation to the chemical concepts introduced and developed through relevant contexts and applications.

The third design criterion, *context-led development of concepts*, is expressed as follows:

> ... chemical generalisations, principles and explanations are only introduced *as and when* they arise *naturally* from or *when needed* in the work on these 'everyday' substances [Ped/TA] (SLB, p. 1).

> Chemical theories, principles and explanations were to be introduced only *as* they were seen to be *needed* for understanding of the work being done [Ped/TA]. Of course, only those topics which turned out to provide a natural introduction to some "worthwhile chemistry" were developed (OGT, p. 9).

In these quotes a tension seems to surface between chemical content and chemical context. On the one hand, a theme or context should "provide a *natural* introduction" to some "worthwhile" chemistry by which is meant, I take it, some worthwhile chemical content. On the other hand, in the last quote and, also in the introductions to the units, it is emphasized that "chemical concepts and explanations *arise naturall*y *from the study of these everyday situations*" (Metals 1989) as and when needed for making sense of the chemical contexts. This raises the important question as to what the developers thought was more fundamental: the new fundamental CTS emphasis (SLB, p. 8), embodied in the themes or contexts chosen, or the traditional emphasis on a solid foundation of fundamental concepts, a question to which I will return in Chapter 5.

The fourth criterion, *variety of learning activities*, mentioned above (4.5.1), emerged during the developmental process and also found explicit expression, albeit with slightly different accents:

> The teaching materials allow a wide *variety of teaching and learning activities* leading to a positive and mature *involvement* by students [Ped/TA] (SLB, p. 1).

> Particular attention was to be paid to encouraging an *interactive teaching* approach in which students would be *actively involved* [Ped/TA] and which would help encourage students' *study skills* and general *personal development* [Ped/A] (OGT, p. 9).

At least from the time of creating pilot materials, to be used by teachers in the Salters' Chemistry Project, another, fifth criterion was articulated: *flexible, teacher-mediated use*.[45]
This idea of flexible use also found expression at the stage of the formal curriculum:

> Further, we want the materials to be used *flexibly*, and it is possible for teachers to introduce replacements for or modifications to whole lessons, parts of lessons and student activities (SLB, p. 1).[46]

> The intention has been that the unit guides should provide *a basis* from which individual schools would develop their *own* teaching materials. ... They should be as *flexible* as possible in use, so encouraging *continual review and development* of the course within each school. (OGT, pp. 7, 9).

4.6.2 Pedagogical, philosophical, and substantive structures

In this subsection I will analyze, in terms of the Schwabian framework and codes introduced in Chapter 2, the two documents pertaining to the overall formal curriculum of Salters' Chemistry: the syllabus (SLB) and the Overall Guide for Teachers (OGT). The first document gives a detailed enumeration of the aims and the assessment objectives of the Salters' Chemistry course with cross-references to the aims and assessment objectives given by the National Criteria of Chemistry (SLB, pp. 2-4; 20-22). The overall teacher guide deals with the design criteria and discusses also in detail the variety of teaching and learning activities used to achieve the set aims (see also Figures 4.6 and 4.7).

Pedagogical structure

The teacher guide gives the following general statement of the aim [Ped/A] of the course:

> ... a complete course which would give a *sound foundation* of chemical knowledge and understanding [Sub] through an "applications led" [their emphasis] approach [Ped/TA] which would be accessible to a *wider* range of students [Ped/A] than those catered for by more traditional courses (OGT, p. 6).

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45 Already in Metals (1984) this criterion of flexibility had emerged: "The materials should be organized in such a way that detailed guidance would be provided and yet they would be capable of being used *flexibly* in the sense that it should be possible for teachers to introduce replacements for, or modifications to, whole lessons, parts of lessons, experiments, etc." See also Campbell (1994, p. 430).

46 Also, in the teaching units such as Metals (1989), it says in the introduction under the heading "Design of materials", "The materials must be *flexible* enough to allow [experienced] teachers to introduce replacements and modifications to parts of lessons, whole lessons or *even whole units* where they feel it is appropriate". On the other hand, and in particular for "those who are starting their career and those who are teaching outside their main specialism" (Metals, 1989), a substantial level of help would have to be given in the unit, also because the Salters' approach meant that many units would contain relatively unfamiliar material (See OGT, p. 9).

The syllabus defines the target group [Ped/A] as "the whole range of GCSE grade A – G" (SLB, p. 2; see also Figure 4.1). Thus, any uncertainty the developers had previously felt about the range of the target group (low, middle and high ability), during the development of the written curriculum (see section 4.5.2), disappeared at the level of the formal curriculum. The course explicitly addresses the full ability range, primarily students of middle ability but supplying additional strategies for the less able as well as the more able students (OGT, pp. 35 – 36).

The syllabus section titled "*Aims of the course*" [Ped/A] starts by giving the following general aims, that is to say, to provide a course in chemistry which will:

- be relevant and appropriate to students who will have no further contact with the subject;
- provide an appropriate body of knowledge and skills for those continuing to more advanced studies in chemistry and other related disciplines;
- stimulate students and create and sustain their interest in and enjoyment of the study of chemistry.

The description of the aims of the course continues (SLB, pp. 2-3) with three sets of aims [Ped/A]. These aims are largely similar to the curriculum orientations on science education introduced in Chapter 2 of this thesis and discussed in Chapter 3 using the labels: *result-oriented* (NSE), *process-oriented* (HPS), and *society-oriented* (STS) science education (see Figure 4.6).

These three sets of aims and the associated specific assessment objectives can be seen as the detailed elaboration of the balance of "theory, practicals and relevance" (G92a) sought by the Working Party of the National Criteria of Chemistry (Garforth, 1982a).

A set of aims and objectives stated in such detail guide but can also seriously constrain any attempted alternative teaching scheme such as Salters' Chemistry. The point is, that at the stage of the formal Salters' Chemistry curriculum the developers had to "match" fully and explicitly their written teaching units to the aims and objectives listed above, that is, to a much greater extent than in the earlier phases of the development. Thus, the developers could no longer focus primarily on the curriculum orientation or CTS emphasis they preferred, that is, on the development of a society-oriented and applications-led chemistry course.

As we saw in section 4.5, to obtain acceptance as an exam course, it was necessary to add some theoretical concepts to the first submitted GCSE Salters' syllabus in order to comply with the required *result-oriented* science demands of the National Criteria of Chemistry. This increases the *tension between context and content*, a tension which has manifested itself during the development of the Salters' Chemistry course, as we will discuss in detail in Chapter 5 on the development of the unit Metals.

Further, the set of aims and objectives with regard to students' abilities and skills leads to a greater emphasis on *process* objectives than originally envisaged by the developers. This introduced to some extent a second tension into the formal Salters' Chemistry curriculum, this time between *context and process*, as we will see in Chapter 5. Hence, the Salters' Chemistry curriculum, originally and primarily intended as a relevant and *context*-led chemistry course aiming at raising the chemical awareness of future citizens, now has to integrate in its course both detailed *process* objectives as well as demanding *result* objectives (Figure 4.7).

The OGT (pp. 38-68) contains a detailed description and analysis of the *variety* and frequency *of teaching/learning activities* used in the course [Ped/TA], as well as strategies for introducing and managing them. The developers feel confident, on the basis

Figure 4.6 Aims of the Salters' Chemistry Course

RESULT-ORIENTED SCIENCE EDUCATION (some terms put in italics refer to STS aspects)

To encourage students to relate their chemical knowledge and understanding to:

(a) *making* and *using* materials;
(b) chemical structure and the behavior of materials;
(c) the development of chemical patterns and principles;
(d) the *environment*.

PROCESS-ORIENTED SCIENCE EDUCATION

To develop students' abilities and skills in:

(a) formulating hypotheses and designing investigations;
(b) performing and interpreting experiments;
(c) evaluating data, making decisions and solving problems;
(d) communicating findings.

SOCIETY-ORIENTED SCIENCE EDUCATION (same terms put in italics refer to HPS aspects)

To provide the opportunity for students, through practical studies on the behavior of familiar substances and discussion of familiar experiences, to

(a) appreciate that the study of chemistry is relevant to everyday life;
(b) appreciate that the applications of chemistry may be both beneficial and detrimental to the individual, the community and the environment;
(c) become well informed and hence confident citizens in a technological world;
(d) realize the strengths and limitations of the ways scientists attempt to solve problems and the application of these methods to other disciplines;
(e) become aware that the study and practice of chemistry are human activities which are subject to social, economic, technological, ethical, and cultural influences and limitations.

of previous trials, that these varied activities will serve as the means to realize the aims and objectives sought.

According to the activity analysis performed (OGT pp. 38-45), the following activities are used most frequently in the units: teacher-led introduction/explanation/discussion, teacher-student discussion, data analysis/interpretation/translation, and class practicals. The latter activity, *practical* work, is seen by the developers as being "*central* to the Salters' Course" (OGT, p. 57). The discussion in the teacher guide deals to a great extent with non-traditional or "less familiar teaching strategies" (p. 37) such as small group discussion, the use of computers, and the managing of role play; traditional teaching activities receive less attention.

Both SLB (appendix D, pp. 23-39) and OGT (pp. 68-79) discuss at great length the *internal* assessment model with regard to practical skills and individual assignments which make up 40% of the total assessment against about 20 – 25 % in traditional courses.[47]

In brief, the pedagogical structure entails, besides a *relevant emphasis* on chemistry, quite a lot of *practical* chemistry, while its chemical content is appropriate for the full ability range of students. This gives rise to two curriculum tensions: (i) between context and content and (ii) between context and process. More will be said about these tensions at the end of Chapter 5 after the lesson and unit analysis of Metals (1989).

Philosophical structure

Both SLB and OGT also contain statements which express views of science [FS] and/or chemistry [FC]. The ambition to develop a course which would show the relevance of chemistry in the real world led developers (SLB, p. 1) to:

> ... rethink our ideas of what *theory* is *appropriate* to teach in such a course. In particular, we found that many of the substances familiar to students are structurally too complex to be amenable to *molecular* interpretation by GCSE students. We have, therefore, developed *explanations* of properties in terms of *macro* structures [FC].

Central importance was given to the *use* of familiar materials *in relation to* their *behavior* [FC] as can be judged from the theme-based summary of the unit content (OGT, pp. 10-12), the experiments which have been selected for assessment of practical skills (OGT, p. 69) and for individual assignments (OGT, p. 75), and also from the choice of role-play (OGT, pp. 53-57). Chemical-societal concepts such as *source*, *manufacture*, and *use* of materials (e.g. of fabrics, metals, fertilizers, cosmetics and plastics), as well as chemical-societal relationships between properties and use of familiar materials, are mentioned frequently. Furthermore, in the syllabus it is stipulated for individual assignments that students should have:

> a wide scope both in the *choice* of topics and in the *mode* in which the work is presented ... the only *constraint* is that the work should illustrate chemical knowledge and understanding within a *social, environmental, industrial and technological context* (SLB, p. 30).

So, design criterion two, *relevance*, receives primary importance here. Besides the consequences for teaching and assessment, the society-oriented emphasis of the course has, according to the developers, the following practical consequences:

- Since many of the everyday substances cannot be bought on requisition to a *laboratory supplier* teachers or technicians have to go to *local shops and markets* (OGT, p. 18).
- *Common* names of chemicals are used when these chemicals are met by students in everyday experience or activities; once the activity moves to a study of the chemistry of a substance, the *systematic* chemical name is used (OGT, p. 13).

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[47] See Smith (1988, p. 111). Neil Smith, whose school became from September 1986 onwards a Salters' Chemistry Project school, performed a detailed comparison of the assessment model of the Salters' Chemistry course, Nuffield courses, and a number of traditional courses.

- Since the course *overlaps* with other subject areas, in particular with "biology, physics, geography, home economics and craft, design and technology" (OGT, p. 19), liaison with other school departments should be established.
- Visits to local chemical industries or contacts with relevant organizations are encouraged e.g. Fire Brigade (OGT, p. 19).

In brief, this part of the philosophical structure is about relevant chemistry in real life, including technology and industry (see Figure 4.7). It is not primarily about pure substances, but rather deals with the sources, manufacture, and use of materials. These are mostly mixtures and as such go beyond the pure school chemistry conception referred to in Chapter 1 of this thesis.

The OGT also discusses some points concerning the methodology of science [MS], saying that "the balance of the [practical] work is more towards students *discovering* scientific principles for themselves and *solving problems* rather than completing experiments to *illustrate* theory taught earlier" (OGT, p. 57). For problem-solving the developers use the following definition (OGT, p. 62):

> Students planning, devising, carrying out and evaluating a method to solve a problem. The problem could be *technologically* orientated and could be open-ended and ideally would be set in a real life context.

Problems can be open or closed. An open problem may either "involve the possible use of many different routes to achieve a solution or may have a number of acceptable solutions" (OGT, p. 62). A closed problem has only one solution. Enough time has been made available in the course for students "to be given some open problems to solve" (OGT, p. 62). Problems should as far as possible arise *naturally* for the student during the course, although they might have to be set and clarified by the teacher (OGT, pp. 62-64). This type of activity makes it possible for the course or teacher to address, as much as needed, the required science process objectives, but they can thereby also lead to a tension between the time required to deal thoroughly with these process aspects and the time needed to deal with contextual or relevant aspects of the course.

Substantive structure

The substantive structure of the formal curriculum of Salters' Chemistry had to coincide, after the necessary matching, with the National Criteria of Chemistry (Figure 4.7). Thus, SLB (section B, pp. 15-16) lists the "chemical principles" [Sub/CT] developed during the course, while section C (pp. 17-18) does so for the "principal substances and reactions" [Sub/CC], just as Section D (p. 19) does for the chemical "techniques and tests" [Sub/CT] (see Figure 4.7).

The OGT goes further by giving an elaborate analysis of the chemical concepts developed during each year of the course (OGT, Section 3, pp. 22-29). This leads to the interesting observation, already mentioned above, that:

> In *some* cases the *logical* development of concepts does dictate a *teaching sequence* and this is noted in the recommendations (OGT, p. 22).

It leads to a recommended teaching sequence of units for Years Four and Five, but interestingly not for Year Three. The teaching order recommended adheres to the following guidelines:

- Macroscopic chemistry first (predominantly in Year Three)
- Corpuscular chemistry as a later, central emphasis (Year Four and Year Five)
- Introduction of concepts on a need-to-know basis
- Spiral revisiting of qualitatively introduced concepts in different contexts
- Increasing sophistication of qualitative concepts
- Increasing mathematical demands

For practical skills developers do not assume a specific sequence except for purposes of assessment. Some practical skills are "assumed to be mastered prior to Year Three" (OGT, p. 58).

The National Criteria of Chemistry only specify a *core* chemical content, which makes it possible to teach and assess topics and issues "from areas of social, economic, environmental and technological applications of chemistry" (SLB, p.1) more than the recommended 25%. The opportunity to teach chemical-societal-technological (CTS) content can amount to about 40–50% of the total content as it did in the case of Salters Chemistry.[48]

In brief, the substantive structure of Salters' Chemistry is governed to a certain degree by the *logical* development of concepts. Corpuscularity is given a *central*, although not a primary focus, while macro-chemistry is emphasized, especially in Year Three.

Figure 4.7 Salters' GCSE Chemistry: Structure of the formal curriculum

Categories	**Specifications taken from OGT (1988) and SLB (1992)**
SUBSTANTIVE STRUCTURE	**LOGICAL DEVELOPMENT OF CHEMICAL CONCEPTS AND PRINCIPLES**
Chemical concepts	States of matter, solutions and solubility, dispersions; Elements, compounds; pure substance, mixture; the Periodic Table; Symbols, formulae and equations; quantitative chemistry; simple balanced equations; Atoms, molecules and ions; structure of atom – electrons, protons and neutrons Speed of reactions; affected by concentration, surface area, temperature, and catalysts; Reversible reactions; enzyme reactions; Energy changes in chemical reactions (exothermic, endothermic), conversion of energy; Acids, bases and salts; Oxidation and reduction (in terms of gain and loss of oxygen only); Electrolysis.

48 See Smith (1988, p. 112) who, after analyzing the assessment model and specimen papers, arrives at a percentage of *ca.* 50 % for what he calls the *utilitarian* aspects. See also Harding (1986).

Figure 4.7 Salters' GCSE Chemistry: Structure of the formal curriculum (continued)

Chemical relationships	Relationships (external) with real world e.g. common names; with physics, technology, society; Particulate and kinetic theory of matter explain reversible physical processes Structure and bonding (ionic, covalent), simple ideas in terms of microscopic models; Relation between properties and structure, e.g. hardness related to packing of particies: Macrostructure of materials.
Chemical techniques	Methods of separation e.g. filtration, paper chromatography, electrolysis, and flotation; Methods of purification e.g. simple and fractional distillation, evaporation, crystallization; Standard tests e.g. for hydrogen, oxygen, carbon dioxide, water, metal ions; Testing for soil nutrients, proteins, fats, sugars; titration.
PHILOSOPHICAL STRUCTURE	**RELEVANCE, CHEMISTRY FOR INDUSTRY AND EVERYDAY LIFE; SOURCES, MANUFACTURE AND USE**
Foundations of science	Strength and limitations/human activity.
Methodology of science	Processes of enquiry e.g. hypothesizing, experimenting, evaluating; Problem solving e.g. control variables/comparative testing; Discovering scientific principles; use of models.
Foundations of chemistry	Use of familiar materials in relation to their behavior; Social, economic, environmental, industrial, and technological contexts; Theory/explanations of properties as much as needed in terms of macro-structures.
Methodology of chemistry	Making and analyzing; Practical skills e.g. using a chemical balance, pipette.
PEDAGOGICAL STRUCTURE	**WORTHWHILE, PRACTICAL, AND RELEVANT CHEMISTRY**
Aims	Accessible to full ability range of students, providing whole range of GCSE grade A – G to: (i) students who will have no further formal contact with the subject; (ii) students continuing to more advanced studies of chemistry and other related disciplines; Sound foundation of chemical knowledge and understanding; Develop students' skills/understanding of science processes; Develop study skills/personal development; Practical studies of familiar substances and of relevant applications; The importance of chemistry in industry and in everyday life.
Teaching approach	Familiar contexts: materials/phenomena first; applications led; Variety of interactive classroom activities/central value of practical work; Chemical concepts as and when needed/drip-feed/spiral revisiting; Teacher mediated, teacher guidance and support.
Learning approach	Motivate students through relevant contexts and various activities; Enable students to develop their own interests and ideas.

4.6.3 Conclusion and discussion

I will now try to give an answer to the question regarding the extent to which the formal curriculum, the last phase in the Salters' Chemistry development process, has developed in a consistent way from the visionary curriculum, that is, from the initial vision and design criteria. As before, I will also look into the changes of the pedagogical, philosophical, and substantive structures of the formal curriculum compared to the visionary curriculum and NCE.

Changes in design criteria and resulting curriculum

First of all, design criterion one, *No preconception*s has now been replaced by guiding conceptions, internally by "what we *all* perceive to be *the structure of chemistry*" (L 92), and externally by the demands of the General Certificate of Secondary Education fulfilled for the Salters' Chemistry course in the *Chemistry (Salters') Syllabus Code 1377*. Design criterion one is not mentioned in the curriculum products of the Salters' Chemistry course, not in the teaching units or in either the syllabus or the teacher guide. The initial uncertainty about the suitability of the course for the *full* ability range has disappeared.

The application of design criterion two, *Relevance,* to the situation of the formal curriculum leads to a choice of contexts constrained more and more by GCSE requirements of content or process, giving rise to the tensions mentioned above between context and content and between context and process.

The application of design criterion three, *Context-led development of chemical concepts*, has led to an increased emphasis on chemical concepts and their sequential and/or logical development. Important too was a greater emphasis on scientific processes over and above the initial emphasis on chemical techniques and practical skills.

Finally, inspection and comparison of Figures 4.3 and 4.7 show that many components of the pedagogical, philosophical, and substantive structures of the written curriculum of Salters' Chemistry did change: they became much more explicit or more detailed, while some important components, as we saw above, were discarded or replaced.

Discussion

All these changes came about, in my analysis, as a result both of the *internal* dynamics of the development process and the *external* constraints acting upon the developers in the form of the National Criteria of Chemistry and later the demands of the GCSE . Furthermore, the changes in substantive, philosophical, and pedagogical structures are probably connected. The greater emphasis by way of the GCSE criteria on cognitive aspects, concepts [Sub] and processes [Phil] of science, seems to indicate a greater priority given, again, to the needs of the more able students [Ped] than was intended originally by the Salters' Chemistry developers.[49] As a result, the formal curriculum of Salters' Chemistry appears to give at least equal weight to the needs of students "continuing to more advanced studies in chemistry and other related disciplines" and

[49] This was, of course, the curriculum orientation paramount in previous O-level courses, and also, with a renewed academic emphasis in the Nuffield courses. See Shayer and Adey (1981).

"those who will have no further contact with the subject" (SLB, p. 2). Salters' Chemistry now had to serve both aims and both target groups equally well which, as we will argue, must be considered as a tall order containing several inherent tensions.[50]

The decision to extend the Year Three course to a national exam course, and to be accepted as such "with the full range of grades on Mode 1" (G/W92a:9), resulted in a relevant chemistry course suitable for the full ability range [Ped/A], thus including the *most able* students. In line with this, Campbell et al. (1994, p. 421) claim for the Salters' Science courses in general that:

> They were in *no sense* developed as courses "for the less able" or for "less well-motivated" pupils but for a wider and more varied group of students which *might* include these categories.

This is claimed in retrospect, while reconstructing the process of development for the purpose of giving a systematic analysis of the "framework, approach, and development process" (ibid., p. 417) of the Salters' projects. As we have seen in sections 4.3 and 4.4, however, this does not apply to the first Salters' project, that is, to the Salters' *Chemistry* project, although it might apply to the later Salters' *Science* projects. Unlike the Salters' Chemistry Project:

> The Salters' Science Projects started off by being in two straight-jackets, one that they had to write a course that looked like the Salters' Chemistry. Two, that they had to write a course that conformed to the national curriculum. So we had our freedom and we had to *constrain* it with the national criteria, but they never had their freedom (G92b:12).

In my analysis of the process of developing teaching materials for the Salters' Chemistry course, based on interviews with the developers, I have been led to a different account for *this* project's focus on the needs of "the less able" and "less well-motivated students".

In order to achieve their aims, the same context- and applications-led teaching approach [Ped/TA] was used by the developers as in the Year Three development, but with a need to create more *coherence among themes* accompanying the evolving *conceptual coherence* already striven for by the developers in the Year Three course; that is, they tried to match a set of coherent themes *via* a set of activities to a set of chemical concepts, while using, as much as they thought necessary, the logical structure of chemistry [Sub] as they all perceived it. This led to a different context- and activity-led *teaching sequence* of concepts. More than in the development of the Year Three course, the developers decided to use or devise a *wide* range of activities [Ped/TA], over and above the standard experimental lab work.

The practical or applied view on chemistry [Phil], already adopted in the Year Three units, was reinforced by the emphasis, put by government and industry alike, on the chemical industry and its products. For example, quite a few Salters' Chemistry units dealt with the making of familiar products such as "mayonnaise or paint" (G/W91:15).

On the other hand, providing an examination course for *all* students, including the most able ones, brought back a greater *academic* emphasis on conceptual chemical

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50 Garforth (1982, p. 130) made this point some years before the start of the Salters' projects as follows: "A daunting task for any syllabus designers!", in her reaction to the DES document *Science Education in Schools – a consultative document* in which it says: "removing material which has little relevance to the pupils needs ... [but] without reducing the intellectual demands made on pupils".

content [Sub] and on chemical theories and *explanations* using those concepts [Phil]. So, at this stage, to quote John Lazonby (L92) once more:

> [The developers] were analyzing what there was, *using* what we perceive, what we all perceive to be *the structure of chemistry*.

Thus, this was the structure of chemistry as the teacher-developers were accustomed to *use*, often in a *tacit* way, either in their own years-long teaching of school chemistry or in their writing of school chemistry textbooks. Since, as discussed above (4.3.3), the developers had decided *not* to pursue Channel A[51], after it turned out that it was not possible to arrive in their first workshop (1982) at a clear view of the "essential chemistry of living" (Garforth, p. 30), their ideas of what they all perceived to be the structure of chemistry were not made explicit by them a priori, but a posteriori, that is during the developmental process (checklist, 'Control'), and at the end of the developmental process (OGT, pp. 22-30). That is, the developers did not try to fulfill condition one: Perform a domain specific analysis of the nature and structure of the dominant school chemistry curriculum (see also sections 1.2.2 & 2.3.2, and Figure 3.10).

At this point it is worthwhile to remember one of the major obstacles, mentioned by Garforth (1983), on the road to development of a radical, alternative school chemistry curriculum:

> "It may well be that there is a *corpus of knowledge* [Sub] without which no syllabus could be called chemistry ... equally it may be that by our *own schooling, subsequent training and teaching we cannot see anything different* adequately filling the space called chemistry at this level" (p. 29).

Therefore, the developers, using a partly implicit notion of the structure of chemistry, went against criterion one, *no preconceptions* of the Salters' education philosophy, although this was attenuated as much as possible by their adherence to criterion two, *relevance*, and criterion three, *context-led development of concepts*, that is, using a need-to-know as well as a bottom-up approach to developing chemical concepts. So, I have argued that the Salters' Chemistry course was initially developed as a course focused primarily on the less able or less motivated pupils, without excluding the more able students whose needs were used to prescribe content and teaching methods for chemistry 11–16. In other words, the course managed to make the experimental approach of the CSE relevant syllabuses viable and productive for the full ability range, that is, one relevant chemistry course for *all* pupils.

Thus, the National Criteria for Chemistry brought to the fore – and imposed – additional, *external* constraints on the developers. These constraints were sometimes favorable in regard to the matter of using relevant contexts, but often were less so, namely, in regard to the required level of standard chemical concepts, theory and explanation. As their meetings with the SEAC committees have shown, the developers had to bend their educational principles here, and more than they wished. Some chemical concepts which they felt were *not* needed to make sense of the familiar contexts that they had chosen for the 13-16 year olds *had* to be fitted in, however superficially or awkwardly, in order to get the course accepted as an exam course.

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51 Channel A entailed (6.2.3): "Identify the chemical concepts and principles which are necessary in order to appreciate and understand the content of any proposed *new* chemistry course".

4.7 Discussion and conclusion

First, I will reflect on the process of transformation of one curriculum level to another. As we have seen above, the design criteria adopted by the developers of the Salters' Chemistry course may lead to different formulations and interpretations of these design criteria when put into practice. Hence, I will now look more fully into the matter of the interpretation of the Salters' design criteria (4.7.1). Secondly, I will answer the question, to what extent has the formal curriculum of the GCSE course *escaped* from Normal Chemistry Education, as embodied in England in the abstracted core chemistry syllabus (see Figures 4.2, 4.4 and 4.7) in terms of the substantive, philosophical, and pedagogical structures of the formal curriculum.

4.7.1 Interpretation of design criteria of Salters' Chemistry

This section has been written partly to respond to the written comments made by the "central planning team" of the Salters' Chemistry Project (W97; W2001, in which were raised objections to the emphasis I laid on design criterion one, *No preconceptions*, on "the target audience of Salters' [being] less able students", and on describing (the "history" of) the developmental process in terms of individuals, not in terms of a team of developers.

First, *how* is design criterion one, *No preconceptions*, to be interpreted? Is it to be interpreted in a *strong* sense: are developers supposed to get rid of any preconceptions with regard not only to the *list* of chemical concepts, but also to the *structure of school chemistry*, that is, concepts as well as the relationships normally used in school chemistry for 13-16 year olds? Alternatively, is design criterion one to be interpreted in a *weak* sense? Are developers supposed to get rid of any preconceptions with regard to the *sequence* of chemical concepts used: how to start, proceed, or end a lesson / unit / course; while the list or structure of concepts is taken by the developers as largely given, that is, accepted by them as it has traditionally been passed on?

Second, *how* is design criterion two, *relevance*, to be interpreted? This design criterion, too, can be interpreted in both a strong and a weak sense. Are the selected contexts used only to *motivate* students to learn the *given* chemical content? Or, in a stronger interpretation, do (or should) the selected contexts give rise only to those chemical concepts really needed to make sense of the CTS contexts, and perhaps even introduce some relevant CTS content? Some related queries are: Do the selected contexts for the lessons all stem from a *coherent* theme of the unit? At the level of the curriculum as a whole, how are the themes of the units of the course related? Is the chemical content chosen "worthy of study" as it says, for example, in Metals (1984) and justified by the chosen CTS themes and contexts?

How is design criterion three, *context-led development of concepts*, to be interpreted, especially the phrase "concepts and explanations should only be introduced *when* they are *needed*", as it says for example in the introduction of the unit Metals (1989). Again, there can be a strong and a weak interpretation of what has been termed the *need-to-know principle* involved here (Ramsden, 1997). This is sometimes reflected in the words chosen to formulate design criterion three. For example, Campbell et al. (1994, p. 419) use the phrase "... introduce ideas and concepts *only as* they are needed". This formulation implies that it will *depend* on the context used, how frequent and in what depth concepts will be introduced and developed.[52] This is a stronger interpretation than the one reflected by the phrase, "only be introduced *when* they are needed", as used in Metals (1989), and the other units of the Salters Science course. The latter phrase implies that developers will only *choose* the *time* of introduction or development of a concept, yet the list and structure of chemical concepts is taken as that largely given by tradition. Related queries are: For what or whom do these chemical concepts constitute a need to know? Are they needed to make sense of only the CTS contexts or also, partly or wholly, to understand the conceptual structure of school chemistry as traditionally perceived?[53] Are these concepts needed for future citizens or for prospective chemistry or science students, or for both?

The meaning of design criteria four, *variety of teaching and learning activities*, seems to be relatively straightforward, but, as we will see in Chapter 5, it still allows various interpretations.

The meaning of the last criterion, *flexibility*, seems rather clear, but it allows, again, two kinds of interpretations. For example, what does it mean for teachers to be allowed and even encouraged "to introduce replacements and modifications to parts of lessons, whole lessons or even *whole units* when they feel it is appropriate" (Metals, 1989)? Should teachers be encouraged to make these changes at lesson and even unit level while retaining the essence of the Salters' approach to chemical education as embodied in the adopted design criteria? Having done so, should they, if and when possible, trial any changes they have made in the course for effectiveness in their classrooms? Would this imply that teachers are seen as co-developers, subjected to the same standards of empirical evaluation as the original developers? Or, taking a stronger interpretation, are teachers free to use "the course as a starting point from which they could develop their own teaching syllabus" (Metals, 1989), whether it is in line with the Salters' design criteria or not? Should these changes, at unit or course level, be trialled for effectiveness?

The problem of the interpretation of the design criteria is compounded by the fact that the design criteria, as the developers have repeatedly emphasized, are articulated and operationalized *during* the developmental process from 1982-1990. Therefore, during the design process the meaning of the initially adopted design criteria might change as a result of these processes. The trialling of the designed units might even lead to the addition or deletion of design criteria. For example, design criterion four, *variety of teaching and learning activities,* was largely articulated or discovered during the course. It evolved from an initial wish to offer students a greater and different variety of

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52 *The New Fowler's Modern English Usage* (1996) gives the following explanation of the meaning of the locutions 'when', 'as and when', and, 'as and if': 'when' refers only to the time, 'as and when' refers to time and frequency, while 'as and if' refers to time, frequency, and condition.

53 Ramsden (1997, p. 698) explains that it is "difficult to *cover* all aspects of these ideas in a single context", so for the purpose of understanding these chemical ideas *they need to be revisited* at other points of the course units and in more depth. This has also been termed the *'drip-feed'* approach to conceptual development. Chemical ideas are revisited in order to ensure that pupils learn and understand all the chemical ideas on which they are examined. The "context-and-activity-led" approach to science teaching does not necessarily mean that the contexts of a unit play a leading role over and above their role as starting points of lessons to motivate pupils. Thus, chemical concepts lead the way since *they* are systematically revisited, and not the contexts of the unifying CTS theme (see also 5.2.8).

laboratory experiments (Garforth, 1983), to offering students a greater variety of *all* kinds of practical activities.[54]

As we have seen, design criterion one, *No preconceptions*, has gradually been articulated. Developers have emphasized that they "encouraged those involved in the writing workshops not to think about what students *should* know at the end of the course" (W97). On the other hand, they "did not tell this group of experienced and outstanding teachers to forget all they knew about how an understanding of certain concepts require a *prior* understanding of other concepts" (W97). Thus, according to the developers, design criterion one, *no preconceptions*, refers only to *coverage* of content, and not to relationships between concepts, since they "*needed* people's views of how the understanding of these concepts developed" (W97). This distinction made by the developers and the role of design criterion one during the development process of the Salters' units are further discussed in section 5.2.8.

It is clear that the answer to the central question addressed in this, and also the next chapter, will depend on the *interpretation* we put on these design criteria.

> *To what extent are the design criteria of the units of the Salters' Science such as Metals (1989), taken as the articulation of the visionary curriculum of Salters' Chemistry, adhered to consistently by the developers designing, and by teachers executing, the lessons of the unit Metals?*

If we take a *strong* interpretation of the design criteria, the answer to this question is probably negative. Developers might have preconceptions with regard to the list of concepts and the set of relationships they use for school chemistry courses, both of which to a certain extent also constrain the choice of the sequence of concepts used. Relevant contexts might not be given first place in all lessons, either as starting points or as the dominant focus of a lesson. Chemical concepts may be introduced which are *not* needed in order to make sense of the contexts of the overarching theme. A reasonable variety of activities might be offered, and the unit allows some flexible use by teachers in line with their interpretation of the core criteria of the Salters' approach.

On the other hand, if we take a *weak* interpretation with regard to the Salters' design criteria, the answer is probably positive. In this case it is sufficient if it can be shown that the developers did *not* have a preconception with regard to the traditional *sequence* of concepts: units such as Metals (1989), as discussed in Chapter 5, show *prima facie* a sequence quite different from the traditional sequence. Contexts are used, mostly, to start units and motivate students, and, occasionally, at other places in the units for the purpose of applying acquired chemical knowledge to similar relevant contexts. Concepts are introduced *when* needed, and revisited *as and when* needed to ensure that students of all abilities and aptitudes, ranging from future citizens to future chemists, are properly prepared for their exams. A variety of activities is visible in units, which allows flexible use by teachers and active engagement by students.

The open and provisional character of the Salters' design criteria approach is a great asset to curriculum development. It can lead to a creative application of the adopted design criteria resulting in the development of motivating and cognitively challenging teaching units by teams of researchers, developers, and teachers. At the same time, though, it calls for a thorough *empirical* study to accompany the process of development.

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54 Borgford (1992, p. 7) mentions the fact that it was during a Salters' users workshop that the different categories to classify the evolving variety of activities were first formulated or articulated.

Ideally, we would like to research the processes of deliberation, articulation, and operationalization as they go on in, what could be called, the vision room and the designer room. Such a study might be something analogous to the research of the teaching and learning processes in the classroom. Failing such an empirical study of the processes occurring in the vision room and designer room, it is only possible to resort to interviews and document analysis, as we did for the Salters' Chemistry course (Chapter 4). In the case of a concrete teaching unit, here Metals (1989), we can perform an *empirical* study of the teaching and learning processes in the classroom, followed by a consistency analysis of the content of the lessons of the unit Metals (1989).

Reflection

In 1997 I sent a first draft of (what is now) Chapter 4 of this thesis to the developers for comments. Their main criticism was "we found parts of the chapter misleading, both in terms of the history of the project or in terms of our strategic thinking" (W97). First, my aim was not historical (see also section 1.1.2), but to give in this chapter a *reconstruction* of the developmental process of the Salters' Chemistry course on the basis of interviews and relevant educational documents and publications. What I set out to do was to reconstruct the developmental process in light of the problems of structure and escape and of the framework I used to solve them (see further Chapter 6).

Secondly, the developers objected to my attempt to "measure" the Salters' Chemistry course "against a predetermined framework" (W2001). My answer to both objections is that the *reconstruction* I make should be assessed in terms of its usefulness or fruitfulness in describing and explaining curriculum phenomena (see further section 6.4.4). For example, as I have tried to show in this chapter, the steady decrease in the degree of escape from Normal Chemistry Education (Figure 4.4) in the process of *development* can be counted as such a phenomenon, which we will encounter again in Chapter 5. In this way I hope to show, as the developers put it, "how a study which sets out to evaluate against predetermined criteria can be an illuminative study" (W2001).

4.7.2 Changes in substantive, philosophical and pedagogical structures

The *substantive structure* of the Salters' Chemistry GCSE course, compared to a traditional O-level course, initially contained a somewhat *reduced* load of chemical concepts [Sub/CC] and relationships [Sub/CR], while retaining about the same set of standard chemical techniques [Sub/CT]. The concepts and relationships were put in a teaching sequence partly informed by, and consistent with, the structure of chemistry as the developers perceived it, not in a top-down hierarchy, but bottom-up led by contexts and activities, and starting at the observational and manipulative level via low-level generalizations moving to more abstract relationships and theories. The developers did not escape *fully* from substantive structure of NCE, but they did to a certain degree, since many of the usual concepts were retained. As we have seen above, the ruling of SEAC brought back in most of the concepts which had been excluded by the developers.

The *philosophical structure* of Salters' Chemistry, as mentioned above, moved away from theoretical chemistry and towards applied chemistry by emphasizing relevance and use. The developers did not escape *fully* from the philosophical structure of NCE, but nevertheless they did try to look seriously for applications of chemical knowledge to familiar phenomena and materials, instead of using 'academic' applications as had been customary in traditional O-level chemistry.

The *pedagogical structure* of the Salters' Chemistry GCSE course initially focused on the needs of the majority of students, the less and moderately able, but at a later stage had to consider the needs of the most able students as well, in particular by incorporating explanation using abstract chemical concepts. At a later stage the original aim of chemical awareness for the future citizen had to compete with the traditional aim of preparing future A-level candidates in an exam course for the full range of grades. The context-led teaching approach evolved into a context- and activity-led teaching approach using a varied set of learning activities including customary lab experiments. The developers did escape from the pedagogical structure of NCE by devising a context-led teaching sequence which differed from the traditional theory-based sequence. There also increasingly surfaced in-built *tensions* both with regard to the target group, the less or more able students, and with regard to the aims set, chemical awareness and/or academic preparation. This raises the question, whether both of these aims can be realized.

Finally, as is clear from the analysis and discussion so far, the developers had – by working out the consequences of the *visionary* curriculum (4.2) into detailed teaching materials (First trial, Year Three, GCSE) – *to a certain extent* managed to "break away from the traditional mould" (Garforth, 1983). In other words, they had escaped from NCE as it existed in England in the 1970s, that is, from traditional O-level chemistry; but they did this in different degrees with respect to the substantive, philosophical, and pedagogical structures which make up NCE. In the next chapter, *Analysis of Metals*, *a unit of the Salters' Science curriculum*, we will see how these in-built tensions of the pedagogical structure of the Salters' Chemistry course came to influence the philosophical and substantive structures of the Salters' Science curriculum, both in the designed curriculum and in the taught curriculum of a particular unit.