Context-based chemistry: the Salters approach

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Table 1: Main storylines and chemical ideas in the first five units of the course

Storyline	Chemical ideas used
The Elements of Life is a study of the elements in the human body, the solar system and the universe.	Amount of substance Atomic structure Atomic spectroscopy Periodic Table: periodicity, Group 2 Chemical bonding Shapes of molecules
Developing Fuels is a study of fuels and the contribution that chemists make to the development of better fuels.	Reacting masses and molar volumes Thermochemistry Homologous series Alkanes Structural isomerism Catalysis Entropy (qualitative)
From Minerals to Elements is a study of the extraction and uses of two elements, bromine and copper.	Ions in solution Reacting masses and molar concentrations Electronic configuration (s, p and d orbitals) Types of reactions (redox, precipitation, acid-base) Group 7 Molecular and giant (network) covalent structures
The Atmosphere is a study of two important chemical processes, the depletion of ozone in the upper atmosphere and the greenhouse effect in the lower atmosphere.	Interaction of matter and radiation Rates of reaction (qualitative) Halogenoalkanes Reaction mechanisms: nucleophilic substitution, radical reactions Chemical equilibrium
The Polymer Revolution tells the story of the development of addition polymers, many of which were the result of 'accidental' discoveries.	Addition polymers Alkenes Reaction mechanisms: electrophilic addition Alcohols Geometric isomerism Intermolecular forces Properties of polymers in relation to structure

Table 2: A map of the unit, The Elements of Life (EL)

ACTIVITIES		CHEMICAL STORYLINE		CHEMICAL IDEAS	
EL1	How do we know the formula of a compound?	EL1	What are we made of?	1.1	Amount of substance
EL2.1	How much iron is in a sample of iron compound?	EL2	Take two elements	2.1	A simple model of the atom
				2.2	Nuclear reactions
EL2.2	Making the most of your study of chemistry				
EL3.1	Investigating the chemistry of Group I and Group II elements	EL3	Looking for patterns in elements	1.2	Balanced equations
				11.1	Periodicity
				11.2	The s-block: Groups I and II
EL3.2	How do the physical properties of elements change across a row on the Periodic table?				
EL3.3	Check your notes on The Elements of Life: Part 1				
EL4.1	How do we know about atoms?	EL4	Where do the chemical elements come from?	2.1	A simple model of the atom
				2.2	Nuclear reactions
EL4.2	Isotopic abundance and relative atomic mass			6.1	Light and electrons
EL4.3	Investigating a spectroscopic technique			2.3	Electronic structure: shells
EL4.4	Radon in the rocks				
EL5	Balloon molecules	EL5	The molecules of life	3.1	Chemical bonding
				3.3	The shapes of molecules
EL6	Check your notes on The Elements of Life: Part 2	EL6	Summary		

Captions of tables:

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Abstract

This paper describes briefly the development and key features of one of the major context-based courses for upper high school students, Salters Advanced Chemistry. It goes on to consider the research evidence on the impact of the course, focusing on teachers' views, and, in particular, on students' affective and cognitive responses. The research evidence indicates that students respond positively to the context-based approach adopted in Salters Advanced Chemistry, and that they develop levels of understanding of chemical ideas comparable to those taking more conventional courses. Finally, issues to do with the development and evaluation of large-scale curriculum projects are considered.

Introduction

This paper has three principal aims: to describe the development of a context-based course, Salters Advanced Chemistry, to draw together the research evidence on the effects of the course, and to identify some of the issues raised for the development and evaluation of large-scale curriculum interventions.

Context-based approaches to the teaching of science have their origins in the early 1980s. If longevity is one mark of impact, then the notion of using contexts as the starting point for the development of scientific understanding must be one of the major movements in science education of the last part of the twentieth century. The 'Salters story' itself already spans over two decades, and has not ended yet! The story began in 1983, when a group of teachers and science educators met at York to discuss ways in which chemistry might be made more attractive to students in school. At this meeting, a decision was made to develop five context-based chemistry units for middle high school (13-year old) students. Now, over twenty years later, a whole 'family' of courses, the Salters courses (named after the sponsor of the original project, and co-sponsor of subsequent projects), has been developed, covering biology, chemistry and physics for the high school age range (11-18) in England and Wales. Moreover, many of the courses have been adapted for use in other countries, including Belgium, China (Hong Kong), New Zealand, Russia, Scotland, Slovenia, Spain, Swaziland and the USA.

In writing about the Salters courses, we have increasingly come to realise that there is more than one 'Salters story' to tell. At the time when the courses were being developed, particularly in the early years, there was very much a feeling of trying to make what seems a good idea in principle work in practice. During this period, relatively little direct reference was made to educational theory or theories about the process of curriculum innovation, though steps were taken to incorporate key findings from educational research into the materials where appropriate. Thus one 'Salters story' can be told about events as they actually happened.

With the passage of time, and the success of what has now become the Salters 'family' of courses, it has become increasingly important to reflect on what has happened and to locate what we have done within wider perspectives on theories and ideas about teaching and learning in science, and more generally about managing change in education. This forms part of the second 'Salters story'. Moreover, the success of the Salters courses has resulted in both teachers and others engaging in research studies to explore aspects of their effects. Thus, over a period of several years, we have been able to gather systematic evidence about the impact of the courses, particularly on students' understanding of science ideas and their attitudes to science. This evidence also contributes to the second 'Salters story'.

This paper forms part of the wider reflection on one of our most successful Salters courses, Salters Advanced Chemistry. This course is one of six Salters courses. These are:

- Chemistry: the Salters Approach (for students aged 14-16, developed in the mid 1980s);
- Science: the Salters Approach (for students aged 14-16, developed in the late 1980s);
- Salters Science Focus (for students aged 11-14, developed in the early 1990s);
- Salters Advanced Chemistry (for students aged 17-18, developed in the early 1990s);

- Salters Horners Advanced Physics (for students aged 17-18, developed in the mid to late 1990s);
- Salters Nuffield Advanced Biology (for students aged 17-18, currently under development).

Thus the family of Salters courses spans the whole of the secondary and pre-University age range in England and Wales. Schools can choose which courses their pupils follow, generally from a choice of between three and five alternatives. All courses have to meet externally-specified criteria in terms of scientific content, and almost all Salters courses have a dedicated assessment system with its own examinations.

We have been asked by the editors of the special issue to write this account with reference to a particular model of curriculum development proposed by Goodlad (1979) and Van den Akker (1998), and modified slightly by the editors of the special issue. In essence, this model sees curriculum innovation as incorporating six dimensions (in Van den Akker's terminology: 'representations'):

- the ideal curriculum represents the original vision, basic philosophy, rationale or mission underlying the curriculum;
- the formal curriculum where the vision is elaborated in a curriculum documentation;
- the perceived curriculum describes the curriculum as perceived by its users, especially teachers;
- the operational curriculum describes the actual instructional process in the classroom;
- the experiential curriculum describes the actual learning experiences of the students;
- the attained curriculum describes the resulting learning outcomes of the students.

In writing any account of a large-scale curriculum intervention, it is of interest to assess the extent of the 'fit' between any proposed model and what happened in practice. Thus, towards the end of the paper, we will examine the extent to which the model is helpful in characterising Salters Advanced Chemistry.

The origins of the 'Salters approach' and the Salters design criteria

The 'Salters approach' was born in the early 1980s from a concern widely-held by both teachers and others involved in science education about current practice and its effects on the uptake of science subjects beyond the period of compulsory study. It was felt that school science needed to become more appealing, to be more relevant to young people's interests and their daily lives, and to involve them in a wide range of learning activities in which they could actively engage. The 'Salters approach' became known as a prime example of a context-based approach.

No specific framework of pedagogic or cognitive theory underpinned the development of any of the Salters courses. Indeed, the development team has argued against the use of one specific educational theory or theoretical framework when designing large-scale curriculum interventions (Campbell et al., 1994). In practice, the Salters projects drew on a number of different theoretical ideas and perspectives. These included ideas about the selection of curriculum content, ideas about how young people learn, and ideas about how to promote and support educational change.

The developments did, however, hinge on two fundamental design criteria, shared by all courses in the Salters 'family':

> The ideas and concepts selected, and the contexts within which they are studied, should enhance young people's appreciation of how chemistry:
>
> - contributes to their lives or the lives of others around the world; or
> - helps them to acquire a better understanding of the natural environment.
>
> Putting this into operational terms, this meant that units of the course should start with aspects of the students' lives, which they have experienced either personally or via the media, and should introduce ideas and concepts only as they are needed. (Campbell et al., 1994, p 418-419)

These design criteria could therefore be seen as encapsulating what Goodlad (1979) and Van den Akker (1988) characterise in their model as 'the ideal curriculum'.

One strength of adopting design criteria which were very broad in nature was that, in the early stages, they provided general direction without the need to specify outcomes at a very detailed level. The content decisions emerged during the development, rather than being specified as the first step. This contrasts with a more conventional curriculum design following a coherent list of predetermined concepts organised following the structure of the subject as in a Normal Science Education in the Kuhnian sense (Van Berkel et al., 2000). Indeed, as the Salters team argue (Campbell et al., 1994), it is only by engaging in the process of developing materials to satisfy these criteria that it becomes possible to establish if such an approach is viable. In their words:

> Curriculum development is the process of discovering the detailed aims and objectives rather than starting with them. Clearly this view has significant implications for the process of development of a national curriculum. (p 420)

The design criteria allowed the developers to pose challenging questions about the science that young people should learn, and drew on the experience and professional knowledge of teachers in answering those questions to make decisions about curriculum content, contexts and learning activities. Additionally, the lack of pressure to specify detailed outcomes at an early stage provided a means by which a variety of different groups who would be interested in shaping the chemistry curriculum (potential funders, science educators, scientists, teachers, policy makers and other bodies with a wide-ranging interest in chemistry, such as the Royal Society of Chemistry) could express their views in order to establish common ground.

The broad design criteria had two other benefits. One of these was that they permitted different interpretations of suitable contexts for subsequent Salters curriculum development projects. The final benefit concerned the ways in which the courses were able to draw on the findings of educational research. The decision not to limit the development to any one education theory enabled the development team to draw selectively and where appropriate on a variety of research studies in order to inform choices about approach and learning activities. For example, there are a number of points throughout the courses where the ideas which had emerged from the constructivist approach to learning influenced particular topics, such as in the development of ideas about quantitative chemistry, electrical circuits, forces and motion and radioactivity. Research has also shown that the use of language by learners, both in writing and speaking has an important role to play in learning (e.g. Barnes et al., 1969, Davies & Greene, 1984; Lemke, 1990; Sutton, 1992). This work supports the inclusion in the courses of activities such as student-student discussion and other individual and small group activities involving language use. Work on gender and science (e.g. Harding, 1983; Whyte, 1986) also influenced decisions about the nature of the course materials.

The two fundamental design criteria have underpinned the more specific aims developed for each of the courses in the Salters family. Salters Advanced Chemistry has the following amongst its intended outcomes:

- to show the ways chemistry is used in the world and in the work that chemists do;
- to broaden the appeal of chemistry by showing how it relates to people's lives;
- to broaden the range of teaching and learning activities used;
- to provide a rigorous treatment of chemistry to stimulate and challenge a wider range of students, laying the foundations for future studies yet providing a satisfying course for those who will take the study of chemistry no further.

The materials produced for the course

The second stage of Goodlad and Van den Akker's model makes reference to the formal curriculum, or the resources produced for teaching the course. This section briefly describes the development of these materials.

The development of Salters Advanced Chemistry began in 1988 at the University of York in the UK, following on from the success of Salters Chemistry, a course for students ages 14-16. Salters Advanced Chemistry was originally developed as a two-year pre-University course for students aged 17 and 18, with an externally-set examination at the end of the course. Since it was introduced into the curriculum in 1990, Salters Advanced Chemistry has seen a steady rise in the number of students taking the course.

Since its initial development, Salters Advanced Chemistry has been modified in response to legislation, and is currently offered in both a modular option, with end of module external assessments, and an examination option with end-of-course examinations. Additionally, students may now opt to study half the course materials for a one-year course. It is worth noting that changes in legislation, coupled with much more detailed specification of the structure and chemical content of advanced level courses, have reduced the considerable degree of freedom the developers had in the early stages of the course in relation to content and approach. None-the-less, the most recent publications have remained true to the original spirit embodied in the design criteria.

Salters Advanced Chemistry has three core publications, now in their second edition (Burton et al., 2000). These are a Storylines book, a Chemical Ideas book, and an Activities folder. These are supported by teachers' guides and technicians' guides. The Storylines provide the 'backbone' of the course, introducing the contexts within which chemical ideas and skills are developed, and indicating where students need to make excursions to either the Chemical Ideas book or to activities form the Activities folder.

The Chemical Ideas book systematically draws together the chemical principles from the individual units and the different parts of the course. Table 1 shows the main storyline and chemical ideas in the first five units of the course, and Table 2 illustrates an example of what is called a 'map' of a unit (in this case the first unit, The Elements of Life), showing how the Storyline links to the Activities and the Chemical Ideas.

[Tables 1 and 2 about here.]

More details of the course contents and structure may be found on the Salters Advanced Chemistry website: www.york.ac.uk/org/seg/salters/chemistry/

One outcome of adopting a context-based approach is that scientific ideas are introduced on a 'need to know' basis. In other words, the science ideas are used when they are needed to help develop understanding of features of the particular context being studied. Thus it is unlikely that any one concept area will be introduced and developed in full in one particular context, as might be the case in more conventional (topic-based) courses. The concept of equilibrium provides a good example of this. It is introduced early in Salters Advanced Chemistry course in the unit The Atmosphere in terms of reversible reactions to explain the role of carbon dioxide in the oceans. It is then revisited in The Steel Story, where redox reactions are introduced. The concept is further developed in Aspects of Agriculture to explain ion-exchange equilibria and this is where equilibrium constants are introduced and used. In Oceans, towards the end of the course, the concept is again revisited and applied to more complex situations such as pH and buffer solutions. In other words the concept of chemical equilibrium is 'drip-fed' through the two years of the course. The approach clearly has implications for the way in which students' understanding of scientific ideas is developed.

Draft material for all the components of the course was discussed and developed at a series of planning and writing workshops held over four years (1998-1992) and involving the developers, funders, science educators, scientists, teachers and representative of the Examination Board which would ultimately set the examinations for the course. The dialogue which took place at these workshops provided a very important means of establishing the priorities of each group and identifying a course structure which enabled the aspirations of the developers for their ideal curriculum to be reflected in a workable way in the formal curriculum. A key element of the earlier workshops involved the identification of the main storylines for the course. These were identified through considerable discussion and on the basis that they best met the aims of the course in relation to showing how chemistry is used in the world of work, and the work chemists do, and how chemistry relates to people's lives.

Later development workshops focused on the assessment of the course. One important factor to note in the context of assessment is that national legislation in England and Wales permitted the course to have its own external examination, provided it met standards set by an external regulatory body which scrutinised all advanced level courses and approved those of a required standard.

Salters Advanced Chemistry is innovative in its assessment in three particular ways. Firstly, in keeping with the context-based approach, the external assessment questions (either in the form of module assessment or examinations) use contexts as starting points. Secondly, it has an 'open book' question, where students are given three weeks to read and respond to questions on a research paper. Thirdly, the formal assessment of practical skills is undertaken by the students' teacher, and based wholly on an individual investigation designed and conducted by the student.

Teachers' responses to the course

One factor of considerable importance to the development team was that teachers should be involved in the design and writing of the curriculum materials. The intention was that the development team as a whole had a closely-shared perception of the aims of the course, taking into account the realities of classroom teaching and perceived student interest. Thus the development of Salters Advanced Chemistry was a collaborative exercise involving over 40 authors and nearly 100 expert advisers. The authors were mostly either science educators or teachers. The initial materials developed were used in a two-year trial before being revised into the final publication form, thus allowing for detailed feedback from both teachers and students to be incorporated into the final version of the course materials. In some cases, the people teaching the course in the two-year trial were contributing authors.

In the later planning and writing workshops, teachers using the materials were encouraged to share their experiences with the central development team, and these informed revisions to the trial materials.

Teachers' responses to a course form a crucial element of the <u>perceived</u> curriculum, as described by Goodlad and Van den Akker. Much of the evidence of teachers' responses to Salters Advanced Chemistry could be characterised as anecdotal, as it has emerged from discussions at development and training workshops. However, a recent change in legislation in England and Wales (Curriculum 2000), resulting in schools having to make new choices about advanced level courses, provided a timely opportunity to explore teachers' perspectives on Salters Advance Chemistry (Bennett et al., in press) and their reasons for choosing to use the course. One aspect of the study explored teachers' experiences of teaching Salters Advanced Chemistry, as compared with experiences of a more conventional course. The study gathered data via a questionnaire from 222 teachers. The average number of years' experience of teaching advanced level chemistry course was eighteen years, with teachers having between four and ten years' experience of teaching Salters Advanced Chemistry. The questionnaire sought teachers' views of the chemistry course they were teaching in six dimensions: student and teacher motivation, chemical knowledge and development of concepts, learning activities, assessment, challenge to teachers, and support for students and teacher. Teachers reported that they found Salters Advanced Chemistry course more motivating to teach, that their students were more interested in chemistry, in terms of both their immediate responses in lessons and their increased likelihood of deciding to go to university to study chemistry. Teachers also felt their students were better able to engage in independent study and take more responsibility for their own learning. However, they reported that they found the course more demanding to teach. The teachers believed that their course gave as good a foundation for further study as more conventional courses. In other words, they did not have any undue concerns about the effects on their students' understanding of scientific concepts. They also reported that their experiences were significantly influenced by in-service support provided for the course, and saw this as central to building their confidence and hence to the success of the course. Taken together, these findings provide strong evidence of a good match between the ideal curriculum as originally conceived, and the curriculum as perceived by those teaching it. Additionally, the study findings also point to the crucial role played by in-service support in maximising the match between the formal and the perceived curriculum.

From the materials to the classroom

Studies of curriculum innovation have revealed that teachers rarely use curriculum materials as intended by their developers (Elliott, 1994; Fullan, 1993; Yager, 1992). In order to achieve as close a match as possible between the formal curriculum and the *operational* curriculum (in the terminology of Goodlad and Van den Akker), several features were incorporated into the design and implementation process. Firstly, the format of the curriculum materials and the accompanying lesson outlines were detailed but flexible. Alternative activities and approaches were provided to suit the teacher's preferred teaching style, the available resources or learners' interests.

Secondly, through involving teachers in the planning, writing and trial phases, the project team tried to ensure that the design of the curriculum reflected the realities of life in the school classroom. It was also hoped that the provision of an in-service programme of support for teachers throughout the development and implementation would minimise the mismatch between what was intended and what happened in practice. This programme enabled teachers using the materials to meet members of the development team and other teachers using the programme to gain familiarity with the approaches, and share experiences of use. The nature of the in-service provision was informed by what the developers felt would be good practice. Reflecting back on the process at this point in time, and with reference to more recent research literature, it is clear that the in-service programme shares all the desirable features of effective in-service provision described by Fullan (1993), Joyce & Showers (1995), and Harland & Kinder (1997) in relation to the nature of the support provided. For example, Joyce & Showers showed that a crucial aspect of successful implementation of a new process is providing teachers with the opportunities to attend workshops where they can learn about and practice new skills, and reflect on their performance, and these formed major components of the Salters in-service provision. The teachers' perception of the significance of support and workshops also resonates with the two key factors identified by Harland & Kinder as essential to the success of a new programme: the gaining of new knowledge and skills, and the opportunity to move towards value congruence, i.e. a shared perception of good practice between developers and teachers. Both the flexibility of the curriculum materials and the extensive in-service support helped in linking the formal curriculum (of the documentation) and the operational curriculum (of the instruction process).

Students' responses to the course

No formal large-scale evaluation programme was designed for Salters Advanced Chemistry, as all the funding was tied to the development to the course materials. However, a number of research studies, both at masters and doctoral level, now exist on aspects of the use of courses in the Salters family (for instance, Banks, 1997; Barber, 2001; Barker & Millar, 1996; Borgford, 1995; Cudd, 1999; Fraser, 1999; Key, 1998). It is interesting to look at the focus of these studies. In the courses developed for students aged 11-16, the emphasis has been on studies of student motivation and attitudes, reflecting the widely-held concerns of teachers about these aspects at this age (for instance, Borgford, 1995; Cudd, 1999; Fraser, 1999). Far fewer studies have explored aspects of students' understanding of scientific ideas. In contrast, most of the studied of Salters Advanced Chemistry have focused on students' understanding of chemical ideas. The most likely explanation for this is that students following Salters Advanced Chemistry have made a positive choice to do so, and questions of motivation and attitude are therefore not paramount in teachers' minds.

One study which has gathered information on both motivation and understanding is that of Barber (2001). Data were gathered from two groups of students at a large post-16 college, one following Salters Advanced Chemistry, and another following a more conventional advanced level chemistry course. There were 60 students in each group, spread over four teaching sets and three teachers. The students had had a free choice over which course to take. The data were gathered via a short self-developed questionnaire and semi-structured interviews. The questionnaire used a mix of fixed response items, free response items and agreement/disagreement scales. These items explored a range of areas including students' reasons for choosing to study chemistry at advanced level, what they found easy and what they found difficult in their course, and their views on how interesting and varied they felt their course to be.

The questionnaire data revealed that students' primary motives for choosing chemistry related to interest and career intentions. Within this, however, there were noticeable differences between the two groups of students, with 45% of students on the conventional course citing career choice as the primary factor and 31% citing interest. In contrast, 40% of students taking Salters Advanced Chemistry had chosen it for interest, with only 20% mentioning career intentions. Salters students expressed higher levels of interest in the course and commented positively on the wide range of activities, such as small-group discussions, internet searches, role plays and project work. Salters students expressed more concern than students on the more conventional course about their abilities to cope with revision and tests.

Interviews were conducted with a subset of five students in each group to probe the questionnaire responses in more detail. Again, the Salters students reported very high levels of interest in their course, and commented positively on the variety of activity and flexibility of approach. In contrast, students on the more conventional course valued its straightforward nature and found it 'comfortable' to study – they liked the predictability of a topic-based approach and fairly traditional teaching. The interviews also revealed that student interest and motivation was maintained at a higher level across the two-year course in Salters Advanced Chemistry than in the more conventional course. In contrast, students on the more conventional course reported a decline in interest across the course, particularly towards the end. This higher level of interest in Salters Advanced Chemistry appeared to be reflected in greater numbers of *Salters* students going on to study chemistry or chemistry-related courses at university.

A particular feature of the Salters Advanced Chemistry course is that students are required to make a visit to a local chemical industry. Key (1998) looked at how students' perceptions of the chemical industry varied during the two years of their Advanced Chemistry course in England. Her sample group consisted of 1200 students, spread amongst three conventional Advanced level courses and the context-based Salters Advanced Chemistry course. Students who gained this firsthand experience demonstrated greater insight into the role of the chemical industry and an increased appreciation of its importance compared to those learning about the chemical industry in other ways. This increased appreciation was most noticeable in the students who had followed the context-based Salters course.

Clearly these findings are limited to two studies. None-the-less, they support a considerable quantity of anecdotal data which indicate that Salters Advanced Chemistry is successful in stimulating and retaining students' interest in the subject in lessons, and influencing decisions to go on to study chemistry at university level. Thus the experiential curriculum is very much in keeping with the aspirations of the developers as envisaged in the ideal curriculum.

The development of chemical understanding

For all curriculum interventions, it is very important to look at what students have learned as a result of the intervention, or, in Goodlad and Van den Akker's terms, the attained curriculum. This is a particularly pertinent issue for context-based courses. As has been described earlier in this paper, context-based courses introduce scientific ideas on a 'need to know' basis to help explain and enrich understanding of features of the particular context being studied. This 'drip feed' or 'spiral curriculum' approach clearly has implications for the development of students' understanding of scientific ideas. At worst, the 'drip feed' approach of context-based courses might hinder the development of understanding of key chemical ideas.

Two studies have yielded evidence on students' understanding of chemical ideas. Barker undertook a large-scale, comparative, longitudinal study of 400 upper secondary level students at thirty-six schools in England following A Level chemistry courses, including Salters Advanced Chemistry (Barker & Millar, 1996). The study employed a series of diagnostic questions on key areas of chemical understanding, administered at three points over an 18-month period. Statistical analysis of matched responses found no significant differences in levels of understanding between both student groups. In the case of the topics of chemical bonding and thermodynamics, the context-based approach appeared to produce slightly better results in students' understanding. In a smaller-scale study, Banks (1997) found that the context-based approach to teaching ideas about chemical equilibrium appeared more effective than the conventional approach.

Because students taking Salters Advanced Chemistry take a different examination to those following more conventional courses, direct comparisons of achievement are not possible. However, interesting and relevant data come from a study by Barber (2001), who used a range of added value performance indicators to compare predicted and actual grades in Advanced level Chemistry examinations for two groups of students, one taking Salters Advanced Chemistry and one a more conventional course. Her study indicated that there was no particular disadvantage or advantage to students in either course in terms of the final examination grade they achieved. Although students took different examination papers, all examinations have to meet externally imposed standards, so the study provides some additional evidence to indicate that the learning of students on context-based courses is comparable with that of students on more conventional courses. As part of her study, Barber also used standard questions from the Royal Society of Chemistry (RSC) annual survey test. This survey of the performance of pre-university students in several major chemical concepts has suggested that students following context-based courses achieve lower marks than those following conventional courses. Barber's study confirmed these findings. However, students at her college following the Salters Advanced Chemistry course obtained slightly better grades overall in their Advanced level examinations than the students taking a more conventional course. As the examinations for both courses are matched for conceptual difficulty, this suggests that students' achievement is linked to the design of the assessment items. The RSC test has a better 'fit' in terms of style of questions for students following conventional courses than those following Salters Advanced Chemistry, so the former group of students obtained better marks. The better grades of Salters students in their Advanced level examination demonstrate the close link between the formal and the attained curriculum.

Conclusions

This paper set out to describe the development of Salters Advanced Chemistry, to draw together the research evidence on the effects of the course, and to identify some of the issues raised for the development and evaluation of large-scale curriculum interventions. Additionally, by structuring the account around a particular model of curriculum development, the paper also points to issues about the applicability of the model, in particular issues to do with large-scale curriculum intervention projects. The Goodlad and Van den Akker model of curriculum development is helpful in pinpointing these issues, as they emerge from the tension in the 'fit' between the model and reality of the development of Salters Advanced Chemistry.

These central issues appear to be:

- What role does theory (or theoretical underpinning) play in curriculum development?
- Who is involved in the development process?
- How can evidence of the effects of an intervention be gathered systematically?

The role of theory in curriculum development

Some interventions appear to be much more closely allied than others to ‘theory’. The terms ‘theory’ and ‘theoretical underpinning’ also appear to be used in a variety of ways to cover theories about learning, theories about what science/chemistry ideas should be taught, theories (in a loose sense) about how the science should be taught, and theories about how new programmes should be developed and implemented. As we have argued in the earlier sections of this paper, we are not overly concerned about ‘theory’ in the Salters developments, and feel that there are considerable advantages to be gained by drawing on a range of theories as appropriate.

It seems to us that the Goodlad and Van den Akker model of curriculum development is more likely to have resonance with groups approaching their intervention from a perspective which is allied closely to a research-oriented, theory-based approach. However, there are other interventions, Salters Advanced Chemistry amongst them, which have their origins in a technological problem solving approach. For these interventions, ‘theory’ and ‘theoretical underpinning’ is not seen as a starting point. Rather, the starting point is a problem which has to be solved, using best available evidence from a variety of sources to offer a solution. This results in the identification of a 'good idea' which, it is hoped, will solve the problem, provided it is possible to persuade people to fund it because they also think it is a good idea which should be tested out in practice. In these cases, theory is simply woven into the innovation as and when the innovation demands, not to justification of the innovation, but to give credence to evidence of the good idea working in practice.

One way in which the Salters courses could be described as having a 'theoretical underpinning', is in the links which have become apparent to the theories of curriculum development and evaluation now referred to as design experiments. The term has its origins in the work of Ann Brown (Brown, 1992) and Allan Collins (Collins, 1993) in the USA. Design experiments draw on the evaluation approaches used in technology and engineering, which aim to explore how a product, developed to solve a particular problem, performs in selected situations. This has clear parallels in educational contexts, where the 'product' being tested is a new programme, developed with the intention of addressing selected problems or shortcomings with existing provision.

A design experiment in educational contexts involves evaluating the effects of a new programme in a limited number of settings. For example, this might involve selecting teachers who teach roughly comparable groups, but who have different teaching styles, and exploring the effects of the new programme on each group of students. The design experiment would then yield information on the circumstances in which the programme is likely to be most successful. Design experiments see the context in which the programme is being implemented as an important factor likely to influence its success, and also acknowledge that those implementing the programme are highly likely to make modifications to tailor it to their own particular situations. Thus, it is accepted that there may be considerable variation in what happens in practice from one context to another, de-emphasising the need for a close match between the ideal and formal curriculum on the one side, and the operational and experiential curriculum on the other.

Who is involved in the development process?

A key message for those involved in curriculum development to emerge from the Salters experience concerns the central role that teachers play through their involvement in the planning, design and trial stages of development. The discussion and negotiation with teachers as 'end users' of the programme results is crucial in maximising the overlap between the aspirations of the developers and what happens in the classroom.

A second reason for a close involvement of teachers in the curriculum development process is specific to context-based approaches. Teachers have been perceived as those who are aware of contexts of interest to their students, and thus are essential in selecting contexts as the starting points for learning. Mayoh & Knutton (1997) caution against the assumption that teachers are aware of everyday experiences and interests of their students and, more fundamentally, Jones (1997) provides evidence that students are hesitant to share their experiences and knowledge-needs with adults in a formal settings such as the classroom. More recently, students from around 40 of countries have been asked systematically about their interests in a range of science-related contexts in the Relevance of Science Education (ROSE) project based at the University of Oslo (see website: www.ils.uo.no/forskning/rose/). Initial analysis of empirical data on student interests in learning through different environmental contexts suggests that, for instance, 15 year olds in Norway are more interested in contexts directly irrelevant to themselves (such as how energy can be saved or used in a more effective way) than in contexts highlighting societal issues (such as benefits and possible hazards of modern methods of farming) (Schreiner & Sjøberg, in press). The use of such data will provide an extra student-based dimension to the curriculum development process.

Gathering systematic evidence of effects

No structured programme of evaluation was formally designed for Salters Advanced Chemistry_because all the funding was linked to the development of the materials. However, any curriculum intervention does raise the question of the extent to which the intervention achieves better outcomes than other approaches. Thus a curriculum intervention certainly sets an agenda for research whether it is pursued or not. If it is pursued, a key question has to be the extent to which it is actually possible to gather evidence from a large-scale curriculum intervention which might conclusively demonstrate that the intervention is better than other approaches. An exploration of the ways in which this question might be answered places the evaluation of curriculum interventions very firmly at the centre of the current debate on the nature of educational research. For some (e.g. Hargreaves, 1996; Torgerson & Torgerson, 2000), the use of experimental techniques (and, in particular, randomised controlled trials) is seen as the only way of providing hard evidence of better outcomes. However, such techniques are only appropriate if different approaches have the same outcomes. For those involved in the development of context-based approaches, it is likely to be the case that the intended outcomes are different in relation to what seems desirable for students to know and be able to do. This makes the gathering of hard evidence of better outcomes very difficult.

The limitations of experimental techniques for the evaluation of curriculum interventions may addressed by adopting the evaluation methods appropriate for the design experiment, as described above, as part of a curriculum development approach for large-scale, context-based curriculum innovation initiatives. Although the potential uses of design experiments has yet to be explored in detail, they so seem to offer a productive starting point.

Despite the limitations of research into its effects, Salters Advanced Chemistry appears to have been a very successful curriculum innovation, judged by its longevity, its uptake, and the findings of research studies into its effects on students' interest and understanding of chemical ideas. There is evidence to suggest that students taking Salters Advanced Chemistry are more likely than their counterparts on more conventional courses to go on to study chemistry or chemistry-related subjects at university. Certainly key groups of funders have been persuaded by the evidence on the effects of Salters Advanced Chemistry, as it resulted in funding for two further Advanced-level courses, Salters Horners Advanced Physics, and Salters-Nuffield Advanced Biology.

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Table 1: Main storylines and chemical ideas in the first five units of the course

Storyline	Chemical ideas used
The Elements of Life is a study of the elements in the human body, the solar system and the universe.	Amount of substance Atomic structure Atomic spectroscopy Periodic Table: periodicity, Group 2 Chemical bonding Shapes of molecules
Developing Fuels is a study of fuels and the contribution that chemists make to the development of better fuels.	Reacting masses and molar volumes Thermochemistry Homologous series Alkanes Structural isomerism Catalysis Entropy (qualitative)
From Minerals to Elements is a study of the extraction and uses of two elements, bromine and copper.	Ions in solution Reacting masses and molar concentrations Electronic configuration (s, p and d orbitals) Types of reactions (redox, precipitation, acid-base) Group 7 Molecular and giant (network) covalent structures
The Atmosphere is a study of two important chemical processes, the depletion of ozone in the upper atmosphere and the greenhouse effect in the lower atmosphere.	Interaction of matter and radiation Rates of reaction (qualitative) Halogenoalkanes Reaction mechanisms: nucleophilic substitution, radical reactions Chemical equilibrium
The Polymer Revolution tells the story of the development of addition polymers, many of which were the result of ‘accidental’ discoveries.	Addition polymers Alkenes Reaction mechanisms: electrophilic addition Alcohols Geometric isomerism Intermolecular forces Properties of polymers in relation to structure

Table 2: A map of the unit, The Elements of Life (EL)

ACTIVITIES	CHEMICAL STORYLINE	CHEMICAL IDEAS
EL1 How do we know the formula of a compound?	EL1 What are we made of?	1.1 Amount of substance
EL2.1 How much iron is in a sample of iron compound? EL2.2 Making the most of your study of chemistry	EL2 Take two elements	2.1 A simple model of the atom 2.2 Nuclear reactions
EL3.1 Investigating the chemistry of Group I and Group II elements EL3.2 How do the physical properties of elements change across a row on the Periodic table? EL3.3 Check your notes on The Elements of Life: Part 1	EL3 Looking for patterns in elements	1.2 Balanced equations 11.1 Periodicity 11.2 The s-block: Groups I and II
EL4.1 How do we know about atoms? EL4.2 Isotopic abundance and relative atomic mass EL4.3 Investigating a spectroscopic technique EL4.4 Radon in the rocks	EL4 Where do the chemical elements come from?	2.1 A simple model of the atom 2.2 Nuclear reactions 6.1 Light and electrons 2.3 Electronic structure: shells
EL5 Balloon molecules	EL5 The molecules of life	3.1 Chemical bonding 3.3 The shapes of molecules
EL6 Check your notes on The Elements of Life: Part 2	EL6 Summary	

Captions of tables:

Table 1: Main storylines and chemical ideas in the first five units of the course

Table 2: A map of the unit, The Elements of Life (EL)