Context based learning in post compulsory education: Salters Advanced Chemistry project

Aprenentatge basat en el context en l'ensenyament secundari postobligatori: el projecte Salters Advanced Chemistry

Christine Otter / University of York. Centre for Innovation and Research in Science Education. Salters Advanced Chemistry (England)

abstract

This paper presents a report of the work carried out by The Relevance of Science Education (ROSE), an international comparative project that aims to highlight the important factors which affect how science is learnt in schools. The paper focuses on context based approaches, with special regard to Salters Advanced Chemistry as well as how context and concepts interact within these teaching resources. It explains how context based lessons are structured, the characteristics of students' own research projects, and modes of assessment of Salters Advanced Chemistry students in England and Wales. It discusses some conclusions about the effectiveness of context based teaching and learning.

keywords

ROSE, Salters Advanced Chemistry, context based approaches, chemistry education, assessment.

resum

Aquest article presenta un informe del treball realitzat per The Relevance of Science Education (ROSE), un projecte comparatiu internacional que té com a objectiu posar de relleu els factors importants que afecten l'aprenentatge de la ciència a les escoles. L'article se centra en les propostes basades en el context, tot parant una especial atenció als materials del Salters Advanced Chemistry i a la manera com el context i els conceptes interactuen dins d'aquests recursos didàctics. S'hi explica com s'estructuren els mòduls, les característiques dels projectes de recerca dels estudiants i l'avaluació dels alumnes que utilitzen aquests materials a Anglaterra i Gal·les. També s'hi analitzen algunes conclusions sobre l'eficàcia de l'ensenyament-aprenentatge basat en el context.

paraules clau

ROSE, Salters Advanced Chemistry, propostes basades en el context, ensenyament de la química, avaluació.

Introduction

The lack of interest many pupils express in science, in particular physical sciences, has been well documented in educational research. Ramsden highlights this in her 2003 study. Another well documented feature is that, especially in lower secondary school, student interest in science is found to drop markedly (Reiss, 2004; Simpson & Oliver, 1990). Furthermore the interest of a pupil in different areas of science appears to be influenced by gender. For example technology is commonly found to be a boys' topic, boys are more likely to be interested in learning practical skills and how appliances function and work whilst girls are more interested in issues that connect the teaching to social sciences, and to social and environmental implications of science (Krogh & Thomsen, 2005). Add to this the fact that many pupils state that they do not find school science to be relevant to their lives (Reiss, 2000) and the challenge for science educators and curriculum developers becomes a more complex one.

The Relevance of Science Education (ROSE) is an international comparative project aiming at

DOI: 10.2436/20.2003.02.71 http://scq.iec.cat/scq/index.html

ISSN 2013-1755, SCQ-IEC Educació Química EduQ número 10 (2011), p. 11-17

«shedding light on affective factors of importance to the learning of science and technology». Research is carried out via key institutions and individuals work jointly on the development of theoretical perspectives, research instruments, data collection and analysis. The project can be accessed on *http://www.ils.uio.no/english/rose/index.html* (fig. 1).

There are now about forty countries taking part in ROSE. The target population is students towards the end of secondary school (age 15). The research instrument is a questionnaire mostly consisting of closed questions with four-point Likert scales.

Areas examined include:

– Pupil interests in learning different S&T topics in different contexts.

– Pupil prior experiences with and views on school science.

– Pupil views and attitudes to science and scientists.

Researchers are able to use the data that has been collected for their own research and it has been analysed in a number of ways. Of particular relevance to this paper is the work of Sjøberg & Schriener (2005). They analysed their data by gender, looking at how interested pupils were in studying a particular scientific topic. It is clear from their summary (fig. 2) that girls across the world favour «people related» science (e. g. «cancer and how we can treat it», «ensuring we have clean and safe drinking water») whilst boys appear to prefer topics exhibiting a less human face such as «inventions and discoveries that have changed the world» and «very recent inventions and discoveries in science and technology».

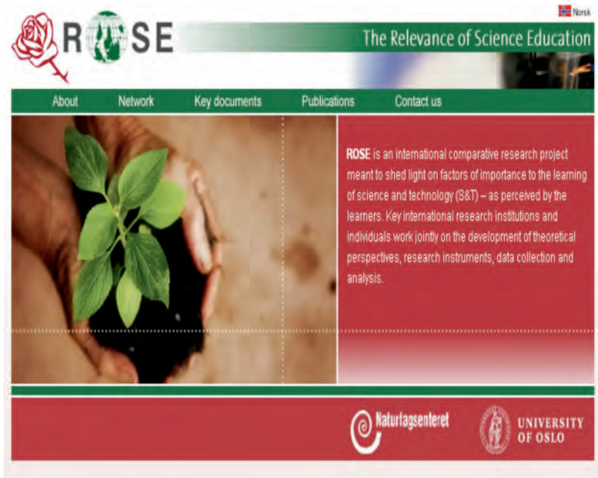

Figure 1. Homepage of the ROSE project.

Matthews (2007) uses ROSE data to conclude that students do not appear to think in terms of scientific disciplines, rather in themes such as health, genetics or the origin of life. His data analysis seems to support the fact that scientific disciplines such as «atoms and molecules» and «how plants grow and reproduce» are of low interest to school pupils.

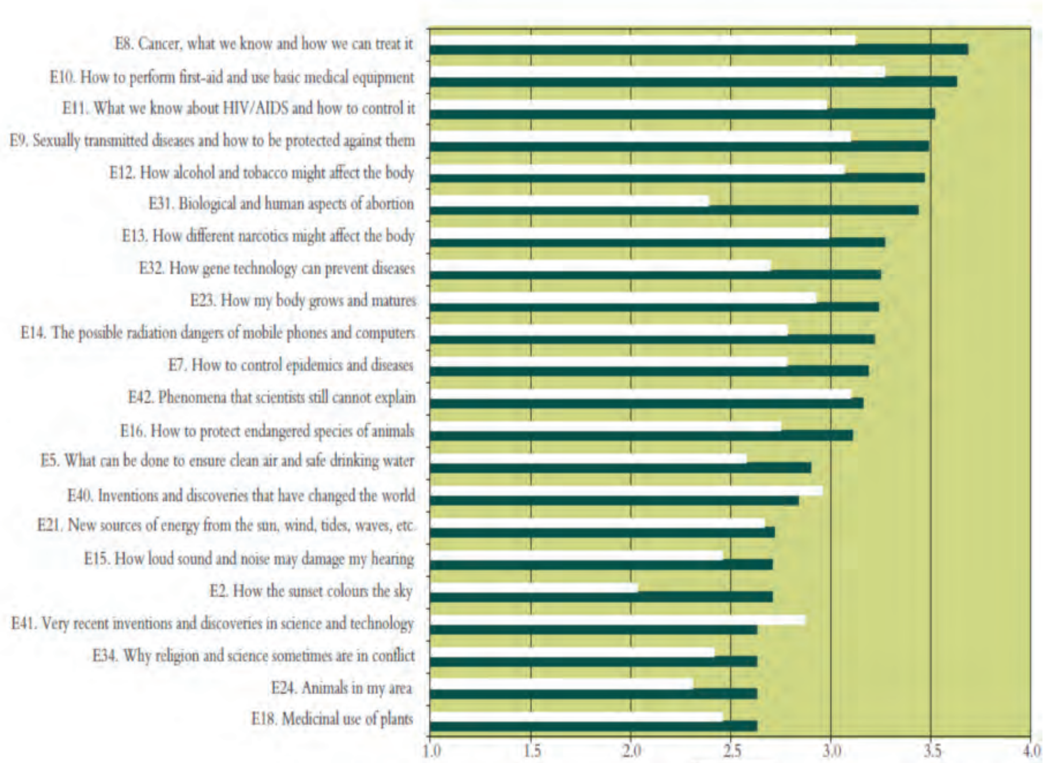

Figure 2. Extract from Sjøberg & Schriener (2005), showing gender preferences for interest in scientific topics.

The emergence of context based teaching and learning, specifically Salters Advanced Chemistry

It is clear from the research that if we are to encourage pupils to engage with science (and in particular the physical sciences) we need to think carefully about how the science our pupils learn is presented. At the Centre for Innovation and Research in Science Education (CIRSE) based in the University of York, England work has been carried out over a number of years using context based curriculum materials as a way of addressing some of the issues cited above. The group came into existence in 1983 and gradually built up a portfolio of courses to meet the needs of secondary science education (originally for pupils aged 14-16).

Before continuing with the story of how Salters Advanced Chemistry was developed it is worth summarising the role of science education for pupils in the English and Welsh education systems. The secondary system is divided into two distinct phases, Key Stage 3 (KS3) and Key stage 4 (KS4) (table 1). During this time pupils usually study science at KS3 and either combined science or separate sciences (biology, chemistry and physics) at KS4. Pupils leave school with General Certificate in Secondary Education (GCSE) qualifications in either science or the separate sciences, and, subject to attaining an appropriate grade, are able to move onto the next level of post compulsory education (KS5). In preparation for university most students study for General Certificate in Education Advanced level qualifications (A levels for short).

Table 1. Summary of the main stages of education in the English schooling system

Key Stage	*Pupil age range*	*School years in the UK system*
KS3	11-13	7-9
KS4	14-16	10-11
KS5	16-18	12-13

Typically KS5 students select four subjects to study at A level. An A level course takes two years (about 360 hours of taught and supervised time) with written examinations and assessment based on practical and other work carried out in school/college and supervised by teachers in both years. The first year is called AS and the second A2. Written examinations are available nationally in January and June of each academic year.

In 1991, following the successful development and implementation of science courses for KS3 and KS4 an innovative new course was launched for pupils entering KS5. As discussed above, KS5 is post compulsory, so not all pupils opt to study chemistry.

Pupils leaving school who opted for pre university courses would typically select three or four subjects to study, specialising in the arts, sciences or humanities. The course produced at York was called Salters Advanced Chemistry, and leads to, the nationally recognised qualification, the GCE Advanced level in chemistry (A level).

The reason it is called Salters is that the course was (and is still) sponsored mainly by the Salters Livery Company, based in the city of London.

The Salters Advanced Level chemistry course is context-led. By this we mean that each topic is based on an up-to-date real-life storyline or issue to engage and motivate students, and to help them learn to apply science ideas to real situations and examples. This story or issue is used as a vehicle to explore underpinning chemical concepts with principles introduced where needed to understand the context. Teachers, academics and industrialists all contribute to the development of the Salters courses, which helps ensure that the contexts are authentic and up to date, and that the courses are attractive for students and teachers.

Example of how a context and chemical concepts interact on the Salters Advanced Chemistry course

One teaching module is a unit from the second year of the course called «Oceans». Here the context is the oceans of the world and the importance they play in supporting life. Students are introduced in the storyline to the idea that approximately 70 % of the surface of the earth is covered by water. Students know the sea is salty and this leads to an exploration of why some substances dissolve in water and introduces the use of enthalpy cycles in order to calculate enthalpy changes of solution and the relationships between a solvent and the substances that will dissolve in it. This allows students to revisit the idea of intermolecular bonding, studied earlier in the course in a new context.

The story then moves on to look at the idea that the if we are to control atmospheric carbon dioxide one method might be to store it in deep natural trenches on the sea floor. This would be in addition to the 35-50 % of carbon dioxide released through combustion of fossil fuels that is removed from the atmosphere naturally through a series of equilibrium reactions (see below).

$CO_2 (g) \rightleftharpoons CO_2(aq)$ reaction 1

$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ reaction 2

$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-} (aq)$ reaction 3

Students need to understand chemical equilibria to be able to engage with this section of the storyline.

Students are then introduced to the fact that the pH of the oceans has remained close to 8 for millions of years. How can this be if $H^+(aq)$ is constantly being produced via reactions 2 and 3 above? At this stage of the storyline students are asked to revise equilibrium constants in terms of concentrations and are reminded of the Bronsted-Lowry theory of acids. This allows them to be able to explore the differences between strong and weak acids and carry out pH calculations. The story then invites students to consider the interplay between the oceans and seashells, chalk and limestone (an almost limitless supply of hydrogencarbonate ions). This introduces the notion of buffering. Students then move on to explore the chemistry of buffer solutions and they are directed to carry out buffer calculations.

Students are next invited to think about the role of our oceans in terms of distribution of thermal energy via evaporation of huge masses of water at the tropics followed by the subsequent condensation of that water vapour in other, colder parts of the Earth. At this point students are directed to study entropy quantitatively to facilitate an understanding of the behaviour of molecules in terms of solids liquids and gases. The unique properties of water such as its high specific heat capacity are a direct result of hydrogen bonding and students are asked to consider how intermolecular forces account for the phenomena observed. Students are asked to think how different our world would be with oceans of propanone instead of water. Their calculations lead them to conclude that approximately four times the volume of rain that currently falls would be needed to maintain similar local temperatures (and that is before fire risks are taken into account!).

The story then goes on to look at the flow of ocean currents in the Atlantic and how and why there is a deep water cold current off the coast of Greenland while the east coast of America benefits from the milder Gulf Stream. This leads to students needing to enhance their knowledge of entropy. A return to the «storyline» sees students reading about the conveyor belt system of cold, deep, salty water currents and warm, less salty water currents nearer the surface of the oceans. Finally this leads to a debate on whether it is possible that the ocean circulatory system might shut down, resulting in another Ice Age in Europe.

By the end of the story students have visited a range of chemical concepts, some of which they have met in previous stories, others that are new to this story.

Drip feeding concepts

You can see from above that that as students progress through a story they access different aspects of chemistry on a «need to know» basis allowing them to understand the story. As a consequence of this chemical themes may need to be revisited across the course. They are introduced then built upon across a number of different contexts in order to build up student knowledge systematically. This «drip feeding» of concepts allows students to only access new ideas as they need them and enables them to revisit

Table 2. Summary of how the chemical concept intermolecular bonding is accessed across the course

Teaching module	*Aspect of intermolecular bonding covered*	*Context and question to be answered*
«Elements of life»	Bond polarity	What are we made of? How do the atoms making up our bodies bond?
«Elements from the sea»	Temporary and permanent dipoles	Halogens and halogenoalkanes in the sea. Why do the different halogens and halogenoalkanes have different boiling points?
«Polymer revolution»	Hydrogen bonding	Dissolving polymers. How do we make laundry bags for soiled linen in hospitals which do not dissolve at room temperature when wet but will dissolve in awash cycle in a washing machine?
«The oceans»	Hydrogen bonding water	The role of the oceans in global temperature control (see above).
«Colour by design»	Comparison of all IM bonding	Fabric dyes. Why do certain dyes bond well to some fabrics but not others?

chemical concepts a number of times across the course, keeping the ideas «fresh». An example is given below. The chemical concept is *intermolecular bonding*. Students develop their understanding of intermolecular bonding in the first four contexts and bring the different strands of the topic together in the final context (table 2).

How is a context based lesson structured?

There are a variety of resources available to support teaching and learning. When a new teaching module is started it is introduced via a story, using the appropriate storyline book (fig. 3). At the appropriate stage in a given story students are directed to the *Chemical Ideas* text book (a student text book containing chemical theory) where they can read about the chemistry they need to understand the story. Students can also complete problems in order to consolidate their understanding. The course also encourages an active approach to learning. Students carry out a range of practical, paper-based, and discussion activities, designed to support their learning. These are also signposted from the appropriate points in the storyline and can be found in the support packs. Activities employing a wide range of teaching and learning styles are integrated throughout the courses. These activities not only introduce content but are designed to develop a wide range of skills.

Assessment

Across England and Wales there are now over seventeen thousand pupils studying Salters Advanced Chemistry at any one time. This approximates to *circa* 17 % of candidates entered for certification at A level. Candidate assessment follows the pattern

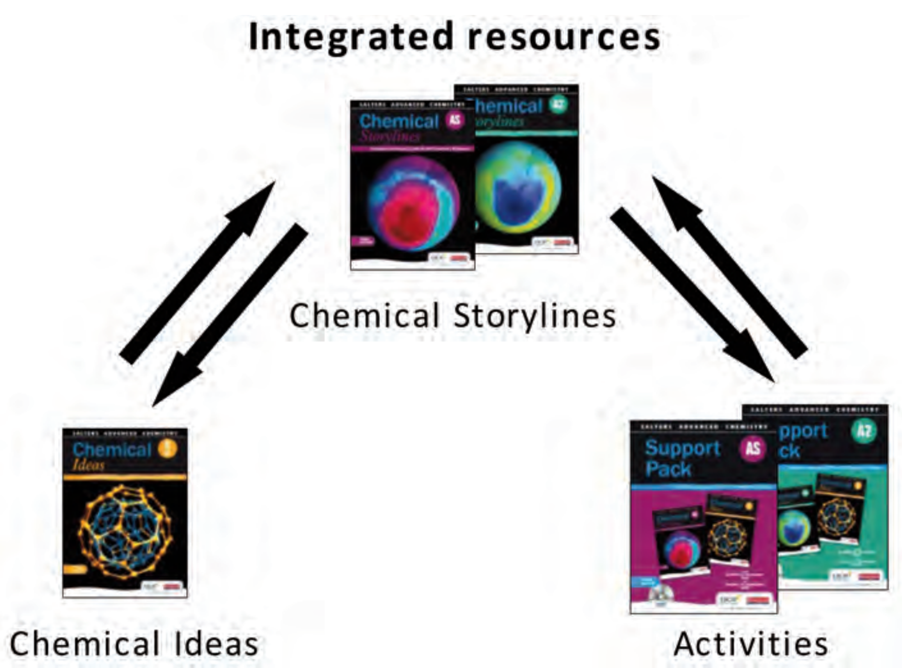

Figure 3. The storylines give the rationale for which aspect of chemistry needs to be explored and signposts where chemical Ideas and activities from the support pack should be used.

shown in table 3. Assessment is provided via a dedicated awarding body, OCR (Oxford, Cambridge and RSA). Written papers are available in January and June of each year, with candidates across the country sitting the same written paper on the same day. Marking of written papers is carried out by the awarding body. In keeping with the context led exposition of the course, assessment questions are also set in context.

In the first of the two years of study (AS year) students are also required to carry out practical work under controlled conditions. The practical tasks are provided by the awarding body and assessed and marked by teachers administering the tasks.

In the second year of the course (the A2 year), students undertake an individual investigation.

The individual investigation

The individual investigation is unique within the assessment available to candidates registered for A level chemistry in England and Wales. Here students are encouraged to pose a question related to chemistry and subsequently plan practical work in order to answer that question. They spend approximately forty working hours on the project and are assessed against the criteria shown in table 4.

Table 3. Summary of the assessment units for Salters Advanced Chemistry

AS	A2
Two written examinations set and marked by OCR. One paper has questions linked to pre release material.	Two written examinations set and marked by OCR.
Practical skills assessed by the teacher and moderated by OCR.	An individual investigation supervised by the teacher.

Table 4. Main areas for assessment in the individual investigation

Skill Area A	Applying scientific knowledge and processes to unfamiliar situations.
Skill Area B	Selecting and describing appropriate qualitative and quantitative methods.
Skill Area C	Selecting, organizing and communicating relevant information with due regard to spelling, punctuation and grammar and the accurate use of specialist vocabulary.
Skill Area D	Making, recording and communicating reliable and Valid observations and measurements with appropriate precision and accuracy.
Skill Area E	Analysing and interpreting the results of investigative activities.
Skill Area F	Explaining and evaluating the methodology and results of investigative activities.
Skill Area G	Demonstrating safe and skilful practical techniques and processes.
Skill Area H	Developing and apply ing familiar and new chemical knowledge and processes in demanding situations.

Individual investigations in the past have included

- Synthesis of biodiesel from vegetable oil, determination of the enthalpy of combustion and evaluation of CO_2emissions
- Comparing titrimetric methods of analysis for copper ions in solution
- Synthesis and analysis of a number of cobalt complexes using ion exchange and a range of titrimetric techniques.
- Determining the most cost effective method to synthesise aspirin on a commercial scale
- Investigation the effect of mordents on dyes

AS well as improving and embedding chemical knowledge Individual Investigations allow students to develop their time management skills, their practical skills and their ability to work in a creative way. Problem solving and communication skills are also strengthened.

A context based/STS approach to teaching science narrowed the gap between boys and girls in their attitude to science

Boys and girls in classes using a context based/STS approach showed significantly better conceptual understanding of science than their gender peers in classes using a traditional approach

What does the research show about the effectiveness of context based teaching and learning?

Bennett, Lubben & Hogarth (2007) conducted a systematic review of the effects of context based approaches in the teaching of secondary science on boys and girls, and on lower ability pupils. Their findings are a compilation of the results from sixty-one individual studies.

The review suggests that there is *reasonable* evidence of the following:

– Girls in classes using a context based/STS approach held significantly more positive attitudes to science than their female peers in classes using a traditional approach.

– Similarly, boys in classes using a context based/STS approach held significantly more positive attitudes to science than their male peers in classes using a traditional approach.

– A context based/STS approach to teaching science narrowed the gap between boys and girls in their attitude to science.

The review suggests there is *some* evidence of the following:

– Boys and girls in classes using a context based approach significantly more often perceived a close link between science, technology and society than their gender peers in traditional classes; there were slight gender-related differences in the way science was linked to technology and society.

– Boys and girls in classes using a context based/STS approach showed significantly better conceptual understanding of science than their gender peers in classes using a traditional approach.

– Girls in classes using a context based/STS approach developed a significantly more positive attitude towards taking a science career compared with boys in these classes.

– Girls in classes using a context based/STS approach showed equal conceptual understanding of science as male peers in the same classes.

– Lower-ability pupils in classes using a context based/STS approach held significantly more positive attitudes to science than lower-ability pupils in classes using a traditional approach.

– Lower-ability pupils in classes using a context based/STS approach developed significantly more positive attitudes towards science than high-ability peers in the same classes.

Lower-ability pupils in classes using a context based/STS approach held significantly more positive attitudes to science than lower-ability pupils in classes using a traditional approach

Publications

You may wish to investigate Salters Advanced Chemistry further. If this is the case the following publications are available.

For students

There are two full-colour student books, one for each year of the course.

Salters Advanced Chemistry: Chemical Storylines AS.

Salters Advanced Chemistry: Chemical Storylines A2.

Salters Advanced Chemistry: Chemical Ideas.

For teachers and technicians. AS and A2 support packs

Two resource files, one for each year of the course are supplied in an A4 ring binder and on editable CD. Each pack contains:

– A wide range of photocopiable student activities including paper based and practical activities.

– End of module tests and answers.

– Student data sheets.

– Teacher's and technician's guide.

These are:

Salters Advanced Chemistry Support pack AS.

Salters Advanced Chemistry Support pack A2.

Useful websites

You may also find the following websites useful.

SAC website:
http://www.york.ac.uk/org/seg/salters/chemistry/

Publisher website:
http://www.pearsonschoolsandfecolleges.co.uk/FEAndVocational/Science/ALevelChemistry/GCEOCR ChemistryBSalters/buy/buy.aspx

Awarding body, OCR:
http://www.ocr.org.uk/qualifications/type/gce/science/chemistry_b/index.html

References

BENNETT, J.; LUBBEN, F.; HOGARTH, S. (2007). «Bringing science to life: A synthesis of the research evidence on the effects of context based and STS approaches to science teaching». *Science Education*, 91(3): 347-370.

KROGH, L. B.; THOMSEN, P. V. (2005). «Studying students' attitudes towards science from a cultural perspective but with a quantitative methodology: Border crossing into the physics classroom». *International Journal of Science Education*, 27(3): 281-302.

MATTHEWS, P. (2007). *The relevance of science education in Ireland*. Dublin: Royal Irish Academy.

SIMPSON, R. D.; OLIVER, J. S. (1990). «A summary of major influences on attitudes toward and achievement in science among adolescent students». *Science Education*, 74: 1-18.

REISS, M. J. (2000). *Understanding science lessons: Five years of science teaching*. Buckingham: Open University Press.

— (2004). «Students' attitudes towards science: A long term perspective». *Canadian Journal of Science, Mathematics and Technology Education*, 4: 97-109.

SJØBERG, S.; SCHREINER, C. (2005). «How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE (the Relevance of Science Education)». *APFSLT: Asia-Pacific Forum on Science Learning and Teaching*, 7(1): foreword.

Christine Otter

Is the curriculum area programme leader for the science PGCE and she is also the Director of the Salters Advanced Chemistry course. She has spent four years teaching A level Salters Chemistry at Bede College in Billingham. In 2000 she was awarded the Salters chemistry teacher of the year award. Previous she has worked for Seal Sands Chemical Company, in the R & D Department. Her special interests are in learning in the interface between science and industry and curriculum development. More information:

http://www.york.ac.uk/education/ourstaff/academic/chris-otter/.

E-mail: *cao4@york.ac.uk*