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# Science Teacher Training in an Information Society (STTIS)

UK Report on WP5
(part 1)

# Training teachers for innovation: energy transfer and the direction of change


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## Introduction

This report presents a set of training materials based on research into the nature of teachers’ transformations of two innovations in the teaching of energy. One is the large scale introduction of the concept of 'energy transfers' in the National Curriculum for England and Wales. The other is the smaller scale curriculum development project 'Energy and Change'.

The training materials provide activities to enable teachers to learn about the innovations and about the nature of the research into their implementation, and to take account of these ideas in their own implementation of the innovation.

These workshop materials are intended to support trainers in developing workshops for teachers to help them understand the innovations and the research, and to implement these ideas in their practice. A suggested structure is that there are two workshops, the first introducing the ideas and providing opportunities for teachers to consider these in relation to their existing practice. They plan and evaluate a trial lesson, which forms a focus for the second workshop in which they plan further work. The materials included are:

- Trainers’ Notes
- Briefing Sheets
- Teachers’ Workshop 1
- Teachers’ Workshop 2
- Activity Resources

It is intended that the materials can be used as either in the form in which they are presented in this report, or electronically as a combination of web-based material and downloadable documents. The materials in this report have therefore been structured in such a way as to allow this flexible use.

## Contents


**Overview** **4**

**Trainers' Notes** **7**

The nature of the innovation 8
Transformations – the results of research 8
About the workshops 9
The rationale of the workshops 9
The structure of the workshops 10
Notes on Section A 11
Notes on Section B 12
Notes on Sections C, D, E and F 13
Notes on Section G 15
Notes on Section H 15
Notes on Section J 16
Notes on Section K 17
Resources 17

**Briefing sheets** **18**

BS1 About the STTIS project 19
BS2 Transferring vs Transforming energy 21
BS3 Energy – why learn about it? 27
BS4 Introduction to 'Energy and Change' materials 31
BS5 The STTIS research into energy transfer and the direction of change 33
BS6 Pupils' understanding: Insulation 35
BS7 Pupils' understanding: Things that 'just happen' and things that don't 36
BS8 Pupils' understanding: Fuels and food 38
BS9 'Energy transfer' and science textbooks 40
BS10 'Energy transfer': case study commentary 43
BS11 'Energy and Change': case study commentary 44
BS12 Dimensions of analysis 46
BS13 Teachers' reactions to 'Energy and Change' materials 49
BS14 Summary of research on teachers' transformations 52

**Teachers' Workshop 1** **53**

Introduction 54
Section A Exploring current practice 56
Section B Learning about the innovation 56
Section C Transformations: content 56
Section D Transformations: beliefs about learning 57
Section E Transformations: values 57
Section F Transformations: contexts, customs and constraints 57
Section G Planning 58
THE ACTIVITIES 59

**Teachers' Workshop 2** **124**

Introduction 125
Section H Evaluation 127
Section J Relating to research case studies 127
Section K Innovation and transformation 127
THE ACTIVITIES 128

**Activity Resources** **133**

AR1 'Energy transfer': case studies 134
AR2 'Energy and Change': case study 137
AR3 Transformations of curriculum innovation: dimensions of analysis 141

**Science Teacher Training in an Information Society (STTIS)**

## Teacher Workshop (UK)

# Teaching about energy

## Overview

## Overview

The curriculum is in a constant state of rapid change. The role of teachers in implementing curriculum innovation is critical, though in the absence of suitable training, the intentions of the innovation may be transformed. The STTIS project is concerned with researching these transformations, and developing materials for training teachers in curriculum innovation.

The training materials presented here are based on research into the nature of teachers' transformations of two innovations in the teaching of energy. One is the large scale introduction of the concept of 'energy transfers' in the National Curriculum for England and Wales. The other is the smaller scale curriculum development project 'Energy and Change'.

The training materials provide activities to enable teachers to learn about the innovations and about the nature of the research into their implementation, and to take account of these ideas in their own implementation of the innovation.

### *The nature of the innovations*

The first innovation studied is the introduction in 1989 into the National Curriculum for England and Wales of the concept of *energy transfer*. Until this time most syllabuses and textbooks used the concept of *energy transformation*. The implication was that there should be a move away from thinking about energy as 'changing from one form to another' and to think of it as staying 'the same kind of thing', with the focus on where it is stored and how it goes from one place to another.

The second innovation studied was the small scale curriculum development project 'Energy and Change'. The aim of this material was to introduce in the 11-16 science curriculum ideas about the causes of change. The key idea is to pay attention to the differences that drive change (for example, temperature differences and concentration differences). To support pupils in understanding the ideas, an abstract picture language to represent change was developed.

### *Transformations – the results of research*

For each of the two curriculum innovations ('Energy transfer' and 'Energy and Change'), we first identified the intended actions implied by the innovations. We then looked for their existence, absence or transformation through teacher case studies.

For the 'energy transfer' innovation, nine case studies of teachers were undertaken. The findings indicate that the intentions of the National Curriculum were often not addressed by these teachers. Their underlying conceptions did not alter, only the terms they used to express them. A similar finding also emerged in the analysis of science textbooks.

The research on 'Energy and Change' drew on case studies of four teachers implementing this innovation in their schools. The results of the research show that the innovation was transformed and adapted in each case to the school's ethos, to the teachers' pattern of work and to what the teachers already knew.

### *About the workshops*

These workshop materials are intended to support trainers in developing workshops for teachers to help them understand the innovations and the research, and to implement these ideas in their practice. A suggested structure is that there are two workshops, the first introducing the ideas and providing opportunities for teachers to consider these in relation to their existing practice. They plan and evaluate a trial lesson, which forms a focus for the second workshop in which they plan further work. The materials included are:

- Trainers' Notes
- Briefing Sheets
- Teachers' Workshop 1
- Teachers' Workshop 2
- Activity Resources

The Trainers Notes give further information about the innovations and the research, the rationale of the workshop and notes on the activities. These are supported by the trainers' Briefing Sheets, which give detailed information about all these aspects. Teachers' Workshop 1 and Teacher Workshop 2 includes all the activities for teachers with supporting notes, and the Activity Resources are for use by teachers to support the activities.

## Science Teacher Training in an Information Society (STTIS)

## Teacher Workshop (UK)

# Teaching about energy

## Trainers' Notes

## Trainers’ Notes

The Overview section at the beginning of these materials gave some brief information about the nature of the innovations and the research, and about the workshop materials. These ideas are expanded on below with references to the trainers’ Briefing Sheets and the teachers’ Activity Resources where more information can be found. These notes also address the rationale of the workshops, the aims and structure of each workshop, and include detailed notes on the individual activities.

In STTIS's research framework any act of communication is necessarily transformative. Communications are not simply 'received' but are re-made, re-constituted, transformed by the receiver. The project's main objective is to investigate science teachers' transformations of educational innovations. Small-scale intensive studies in the participant countries have led to the elaboration of some rules of transformation of innovation and in the development of relevant materials for teacher training. Further information about the STTIS project can be found in *Briefing sheet 1 ‘About the STTIS project’.*

The training materials presented here are based on research into the nature of teachers’ transformations of two innovations in the teaching of energy. One is the large scale introduction of the concept of 'energy transfers' in the National Curriculum for England and Wales. The other is the smaller scale curriculum development project 'Energy and Change'.

### *The nature of the innovation*

The first innovation studied is the introduction in 1989 into the National Curriculum for England and Wales of the concept of *energy transfer*. Until this time most syllabuses and textbooks used the concept of *energy transformation*. This issue discussed further in *Briefing Sheet 2 ‘Transferring vs Transforming energy’*. The implication was that there should be a move away from thinking about energy as ‘changing from one form to another’ and to think of it as staying ‘the same kind of thing’, with the focus on where it is stored and how it goes from one place to another. Some of the scientific issues involved and their implications for teaching and learning are considered in *Briefing Sheet 3 ‘Energy – why learn about it?’*.

The second innovation studied was the small scale curriculum development project ‘Energy and Change’ The aim of this material was to introduce in the 11-16 science curriculum ideas about the causes of change. The key idea is to pay attention to the differences that drive change (for example, temperature differences, concentration differences) and the way that differences tend to disappear. This approach is intended to make accessible to young pupils ideas about the Second Law of Thermodynamics (which in essence says that at the molecular level *things tend to get jumbled up or disordered).* Though a fundamental law of science, it is often not dealt with much at school level. To support pupils in understanding the ideas, an abstract picture language to represent change was developed. Some background information about this project can be found in *Briefing Sheet 4 ‘Introduction to Energy and Change’ materials’*. There are many different examples of the abstract pictures and pupil activities in Section B of Teacher Workshop 1 (Activities B3 to B8).

### *Transformations – the results of research*

For each of the two curriculum innovations (‘Energy transfer’ and ‘Energy and Change’), we first identified the intended actions implied by the innovations. We then looked for their existence, absence or transformation through teacher case studies. A summary of the research undertaken can be found in *Briefing Sheet 5 ‘The STTIS research into energy transfer and the direction of change’*.

For the ‘energy transfer’ innovation, nine case studies of teachers were undertaken. The findings indicate that the intentions of the National Curriculum were often not addressed by these teachers. Their underlying conceptions did not alter, only the terms they used to express them. A similar finding also emerged in the analysis of science textbooks. Examples of the case studies can be found in *Activity Resource 1 'Energy transfer: case studies'*, with further discussion in *Briefing Sheet 10 'Energy transfer: case study commentary'*. Information about the research on textbooks is in *Briefing Sheet 9 'Energy transfer and science textbooks'*.

The research on 'Energy and Change' drew on case studies of four teachers implementing this innovation in their schools. The results of the research show that the innovation was transformed and adapted in each case to the school's ethos, to the teachers' pattern of work and to what the teachers already knew. Examples of the case studies can be found in *Activity Resource 2 'Energy and change: case studies'*, with further discussion in *Briefing Sheet 11 'Energy and change: case study commentary'*.

Key features which emerged from the research as a whole can be found in *Activity Resource 3: 'Transformations of curriculum innovation: dimensions of analysis'*, and details of how this applies to the research on teaching energy are given in *Briefing Sheet 12 'Dimensions of analysis'*. An overview of key findings is in *Briefing Sheet 14 'Summary of research on teachers' transformations'*.

## *About the workshops*

This set of resources contains materials to support trainers in developing workshops for teachers to help them understand the innovations and the research, and to implement these ideas in their practice. A suggested structure is that there are two workshops, the first introducing the ideas and providing opportunities for teachers to consider these in relation to their existing practice. They plan and evaluate a trial lesson, which forms a focus for the second workshop in which they plan further work. The materials included are:

- *Trainers' Notes* These give further information about the innovations and the research, the rationale of the workshop and notes on the activities. These are supported by the trainers' Briefing Sheets, which give detailed information about all these aspects. They also exist as web pages on the training website.
- *Briefing Sheets* These contains background activities for the trainer to use to support them in managing the workshop activities. They include edited materials from the relevant STTIS reports. Being fairly substantial, these are not used for web pages, but are available as downloadable documents from the website.
- *Teachers' Workshop 1* This section contains an introduction to the nature and purposes of the workshop, and all of the activity sheets for teachers. These materials are available both as web pages and as downloadable documents from the website.
- *Teachers' Workshop 2* As for Workshop 1, these activities will be available as web pages and downloadable documents.
- *Activity Resources* This section contains additional material which is required by teachers as part of workshop activities. Like the Briefing Sheets, they include edited materials from the STTIS reports, and are not used for web pages, but are available as downloadable files.

## *The rationale of the workshops*

Teachers' decisions about what they do in their classrooms are dependent on a variety of factors, which can be usefully summarised under the following four headings:

- *Content* – includes the content of the proposed innovation and the content of the existing curriculum, and the perception of the teacher about how the new relates to the old.

- *Beliefs about learning* – include what teachers think that they ought to be doing to support pupils in the classroom, what pupils find easy or difficult and why, and the role and nature of motivation.

- *Values* – include what teachers believe about the nature of their subject, about the purposes of education, about their own role as a teacher, and so on.

- *Contexts, customs and constraints* – includes a wide range from local factors such as classroom layout or the availability of resources, to more global factors such as prescriptions laid down by government, as well as teachers' knowledge of the subject they are teaching, their repertoire of pedagogic strategies, their social skills, and so on

The training materials are modest in scope, and can have only limited impact on these factors. What can be done in these materials, however, is to make teachers aware of some ways in which the curriculum is transformed in implementation, and how these factors affect the transformations that teachers make.

The training materials should have some small impact on teachers' capabilities, and they may have a role in helping them to change some of the contextual factors within which they work, though the materials are unlikely to have any major effect on teachers' values. The materials should however help in making these factors explicit so that teachers can make informed choices in their implementation of new ideas.

If teachers are to be able to make explicit the factors that inform their decisions, they need to do this in the context of their own teaching. Training which is divorced from their own practice is unlikely to have long term consequences. The materials therefore use an approach in which there is an initial and final training session, with a period of some weeks in between in which teachers can use the ideas in their own practice.

## *The structure of the workshops*

The first workshop is designed to help teachers to plan and teach a trial lesson about energy using materials related to the innovations. In a second workshop they will evaluate this trial lesson, drawing on research findings. They will build on the experience of the trial lesson about energy in order to plan more extended sequences of lessons within the schemes of work.

*Teachers' workshop 1*

To support teachers' in planning the trial lesson, in the first workshop they will:

- review their current practice on the teaching of energy;
- learn more about the curriculum innovations;
- review some of the research findings through 'stories' about teachers' implementation of the innovation;
- plan a trial lesson that takes account of the aspects above.

The activities in this workshop are grouped into the following sections:

- Section A: Exploring current practice
- Section B: Learning about the innovation
- Sections C, D, E and F: Transformations of curriculum innovations
- Section G: Planning

*Teachers' workshop 2*

To support them in evaluating the trial lesson and in further planning, in this workshop they will:

- review and evaluate the trial lesson;
- learn more about research work through examples of case studies, relating these and their own experiences to the general findings of the research;
- consider again the factors that affect their planning choices and review the appropriateness of teaching sequences on energy.

The activities in this workshop are grouped into the following sections:

- Section H: Evaluation
- Section J: Relating to research case studies
- Section K: Innovation and transformation

The following notes on each of the sections give additional information to the trainer on running the teacher activities. The activities themselves are accompanied by extensive notes addressed to the teacher on the aims of each activity, background information and rationale, and detailed instructions on what to do. These notes do not repeat this information, and trainers should read the notes alongside the activities themselves. The purpose of these notes is to point to specific aspects of each activity that should be brought out in discussion. The notes will refer at appropriate points to the Briefing Sheets that trainers can draw on for additional information.

As far as possible, activities have been designed to be as independent as possible, in order that trainers can adapt and select activities as appropriate to the interests and needs of different groups of teachers. Where activities do require earlier activities to have been done, then this is indicated in the notes below. In this set of materials, two curriculum innovations are addressed, and the activities have been designed so that it is possible to use them in workshops that address either one of the innovations, or both. For the activities related to the 'Energy transfer' innovation, which are relatively modest in scope, each of the first and second workshops should last about half a day. For the 'Energy and Change' innovation, where learning about the innovation itself takes a substantial amount of time, the first workshop would require a whole day session or two half-day sessions, with another half-day for the second workshop.

## *Notes on Section A Exploring current practice*

The main aims of this section are:

- To review how energy is currently taught throughout teachers' existing science curriculum.
- To evaluate their existing teaching about energy.
- To identify particular areas of existing teaching that they would like to address.

Notes on the activities follow:

*A1 Auditing current practice*

Teachers will bring with them to the workshop their own views about energy and how, and how not, to teach it. The views will influence the way they react to new ideas introduced, and they will certainly want to discuss these views with others during the workshop. This activity is therefore an essential starting point for the workshop, as it allows teachers to raise issues that they want to raise, to set their own agenda, and to relate the remaining activities in the workshop to their own practice.

*A2 Evaluating current practice*

This activity focuses on teachers identifying problems in their existing practice. Most teachers find energy to be a difficult topic to teach, and many have strong views about the nature of the difficulties; it should not be difficult to identify areas that they would like to address in their own teaching arising out of the workshop. Indeed, it is possible that they will identify these issues without specific prompting in the course of Activity A1, and if this is the case then this activity could be omitted.

## *Notes on Section B  Learning about the innovation*

The main aims of this section are:

- To apply the ideas of 'energy transformation' and 'energy transfer' approaches and consider the merits and difficulties of each.
- To clarify some important scientific ideas related to energy.
- To learn about key ideas of the 'Energy and Change' materials.
- To carry out some of the 'Energy and Change' activities using abstract pictures.
- To consider examples of the work of pupils doing these activities.

Notes on the activities follow:

*B1  Forms of energy*

This activity is relevant to the 'Energy transfers' innovation, and could be omitted if the focus is on 'Energy and Change'. An 'energy circus' is typically used to introduce 'forms of energy' to pupils, and teachers begin the activity by doing the circus as pupils would do it. They are then asked to consider the advantages and disadvantages about the 'forms of energy' approach. Background information about this can be found in *Briefing Sheet 2 'Transferring vs transforming energy'*.

*B2  Energy transfers*

This activity is relevant to the 'Energy transfers' innovation, and could be omitted if the focus is on 'Energy and Change'. In this activity, teachers are asked to look at the 'energy circus' but from the point f view of an 'energy transfer' approach. As in Activity B1, they are asked to consider the advantages and disadvantages of the approach. Background information about this can be found in *Briefing Sheet 2 'Transferring vs transforming energy'* and *Briefing Sheet 3 'Energy – why learn about it?'*.

*B3  Comparing approaches*

This activity is relevant to the 'Energy transfers' innovation, but it could also be included as a useful introductory activity if the focus was one Energy and Change'. The first part of the activity is about comparing the two approaches from Activities A1 and A2; It is the energy transfer approach which is used in the 'Energy and Change' materials. The second part of the activity is intended to clarify teachers' scientific ideas about energy. Useful background information on both these aspects can be found in *Briefing Sheet 3 'Energy - why learn about it?'*.

*B4  Energy from hot to cold*

This is the first activity related specifically to the 'Energy and Change' innovation. Background information about this approach can be found in *Briefing Sheet 4 'Introduction to Energy and Change materials'*. It aims to introduce some initial ideas about energy flows and about how they are represented using the abstract pictures. It should be seen essentially as an activity to learn some basic ideas to be used later, and it would be helpful to move on to a later activity where the ideas are applied before engaging in more detailed discussions about the usefulness of the approach.

*B5  Insulation*

This is the second activity related specifically to the 'Energy and Change' innovation. It follows up the work in Activity B4, by applying the ideas introduced in that activity to some more complex situations involving insulation. Teachers may be unconvinced about the possibility of using such an approach with pupils; they may think it is too 'difficult' or 'demanding'. This is an important discussion to have at this point, and for this reason some extracts of pupil discussion about this activity are given. (See *Briefing Sheet 6 'Pupils' understanding: Insulation'* for information about this.)

*B6 Things that 'just happen' and things that don't*

This is the third activity related specifically to the 'Energy and Change' innovation. It focuses on spontaneous and non-spontaneous change, and how these are represented. The notion of one change 'driving' another is central to the 'Energy and Change' project, and so this activity captures the essence of the thinking behind it. The following two activities (B7 and B8) take the ideas further by applying them to a range of more complex situations. Again, this is an apparently difficult idea, and may provoke discussion amongst teachers. Examples of pupil work are given and these are discussed further in *Briefing Sheet 7* '*Pupils' understanding: Things that 'just happen' and things that don't*'.

*B7 Storing energy*

This is the fourth activity related specifically to the 'Energy and Change' innovation. Much of the work here is concerned with mechanical systems, but the main reason for including it in this workshop is that it is built on subsequently in Activity B8, which considers what drives chemical change. The final part of the activity asks teachers to think about these ideas in relation to their existing practice. If they are continuing to work on the following activity it may be better to treat both activities together in considering how they could use these ideas in the curriculum.

*B8 Fuels and food*

This is the final activity related specifically to the 'Energy and Change' innovation. It brings together many of the ideas introduced in earlier activities such as the representation of energy flows, temperature differences, the ideas about spontaneous change and how one change can drive another, and about the notion of energy stored in springs (here applied to 'chemical springs'). This activity requires thorough planning by the trainer to talk through the OHTs and how they relate to each other. Examples of pupil discussion are given, and further information can be found in *Briefing Sheet 8 'Pupils' understanding: Fuels and food'*.

## *Notes on Sections C, D, E and F: Transformations of curriculum innovations*

The main aims of these sections are:

- To compare different ways in which teachers may transform the 'Energy transfer' and 'Energy and Change' innovations.
- To explore factors that may influence the transformations.
- To consider these issues in the light of their own teaching experience.

Notes on the activities follow:

*Section C Transformations: content (C1 Energy transfer)*

These stories bring out key ideas in the research findings. Though the National Curriculum may have produced changes, these are not necessarily directed towards understanding energy in a different way; this may be because of a simple substitution of terms (Story A) or avoidance of old ways of talking but not of thinking (Story B). Some teachers have rejected the new approach completely, for reasons they have thought about and can make explicit. Some see uses in both approaches depending on context (Story D) while others find both approaches problematic.

*Section C Transformations: content (C2 Energy and change)*

These stories bring out key ideas in the research findings. Few teachers would agree that the ideas of this project are not new (Story A), and a few have expressed concern about the *apparent* lack of rigour in the approach using pictures (Story B) though in fact the picture language is firmly rooted in sound thermodynamic principles. Many teachers have shown interest in the approach; those who have used the materials themselves have used them in a variety of ways, transforming the intentions of the curriculum developers. These approaches include creating a new topic (Story C), transforming the meaning (Story D) and integrating on the small scale but not using the ideas in other aspects of teaching (Story E).

*Section D Transformations: beliefs about learning (D1 Energy transfer)*

Teachers’ views about learning include that the transfer concept is too abstract (Story A), that the issue is about the ease of use of verbal terms (Story B), and that different approaches are appropriate to pupils of different ages (Story C).

*Section D Transformations: beliefs about learning (D2 Energy and change)*

Teachers who have not used the materials often have concerns that pupils will find the picture language too difficult (Story A); it is important though to remember energy is anyway a difficult concept and it will not ‘emerge’ directly from first-hand experience. Teachers who have used the materials have been surprised that their predictions about difficulty were exaggerated (Story B) and that the picture language actually made the ideas more accessible (Story C). Some of the activities do not have ‘clear-cut’ answers, and can generate as much discussion amongst science graduates as Y7 pupils; some teachers were attracted to the challenging nature of the activities.

*Section E Transformations: values (E1 Energy transfer)*

One issue here is how teachers see the nature of science itself and its consequences for learning – as the only way of looking at the world, in which concepts are built up in a hierarchical manner (Story A), or as a story about the development of different models, the appropriateness of which being determines by the age and attainment of the learner (Story B). A second issue is about the role of the teacher – as someone who simply implements a given curriculum (Story C) or someone who exercises judgement over its interpretation and transformation.

*Section E Transformations: values (E2 Energy and change)*

The ideas addressed in the previous activity about values related to the ‘energy transfer’ innovation apply equally here. In addition, a further issue is introduced here. About the nature of science education – should the focus be on understanding the scientific dimensions of social and technological issues (Story A), about using the theoretical ideas of science as a way of improving general thinking skills (Story B) or on learning about the ‘big ideas’ of science (Story C)?

*Section F Transformations: contexts, customs and constraints (F1 Energy transfer)*

These stories bring out some of the important constraints that need to be considered when implementing an innovation. These include the national context, for example the availability of training and support (Story A), the school or departmental context (Story B), teachers’ own competencies (Story C) and the influence of textbooks, examinations and syllabuses (Story D).

*Section F Transformations: contexts, customs and constraints (F2 Energy and change)*

The ideas addressed in the previous activity about contexts, customs and constraints related to the ‘energy transfer’ innovation apply equally here. In addition, other issues are introduced here about the relationship between what is taught and what is assessed (Story A), about the relationship between teachers’ subject knowledge and teaching (Story B) and about working with colleagues in a department.

## *Notes on Section G  Planning*

The main aims of this section are:

- To plan, teach and evaluate a lesson drawing on the new ideas introduced in these workshop materials.
- To prepare for the next workshop session by reading case-study material.

Notes on the activity follow:

*G1  Using the new ideas*

Whatever selection of activities are used in this workshop, this final activity should be seen as essential. It is a central feature of the design of these workshops that teachers should have the opportunity to try out ideas they have learned from the workshop in the classroom. In their planning of the trial lesson, teachers are encouraged to make explicit the reasons for their choices, and to think about how they relate to some of the issues raised in the workshop. This may be difficult for some teachers for whom this kind of process is not part of their usual practice. Eliciting this kind of thinking should be a major focus for the trainer in this activity.

## *Notes on Section H  Evaluation*

The main aims of this section are:

- To report back to the group about their experiences in teaching some aspect of energy.
- To evaluate these experiences taking account of the factors that affect the transformation of curriculum innovation.

Notes on the activity follow:

*H1  Evaluating the new ideas in the classroom*

After teachers have had an opportunity to teach a trial lesson using ideas from the workshop, it is very important that they be given the opportunity to evaluate the lesson and to share their ideas with others. The activity gives explicit criteria against which the lesson should be evaluated. These criteria relate to the 'Stories of transformations' from workshop about 'Content', 'Beliefs about learning', 'Values' and 'Contexts, customs and constraints'. Teachers are thus encouraged to make explicit their evaluation. This may be difficult for some teachers for whom this kind of process is not part of their usual practice. Eliciting this kind of thinking should be a major focus for the trainer in this activity.

In preparation for the next workshop, after teaching the trial lesson, teachers should evaluate the lesson against the given criteria, and may be given case study material drawn from the STTIS research (*Activity Resource 1 or 2*) to consider in the light of their own experience. These will be discussed in Workshop 2.

## *Notes on Section J  Relating to research case studies*

The main aims of this section are:

- To consider some examples of case studies and to relate these to the general findings of the research on teachers' transformations.
- To review their own experience and compare it with the case study material.

Notes on the activities follow:

*J1  Energy transfer: research  on teachers' transformations*

In this activity, teachers move from simplified accounts of issues found in the research (the 'stories') to looking at actual case studies. *Activity Resource 1* describes two case studies of student teachers teaching about energy, and *Briefing Sheet 10* gives a commentary about the research findings in general arising from the STTIS research on these case studies. This forms useful background reading related to the questions raised in the activity.

Also in this activity, teachers consider the 'dimensions of analysis' used in the research on teachers' transformations (*Activity Resource 3*) and relate these to their own experience and to the case study work. These dimensions relate to the work on all of the curriculum innovations studied by STTIS. *Briefing Sheet 12 'Dimensions of analysis'* reproduces the information in the activity sheet, adding examples about the energy innovations.

*J2  Energy and Change: research  on teachers' transformations*

As in Activity J2, teachers look in this activity at case study material. *Activity Resource 2* describes a case study of an implementation of 'Energy and Change', and *Briefing Sheet 11* gives a commentary about the research findings in general arising from the STTIS research on these case studies. This forms useful background reading related to the questions raised in the activity. *Briefing Sheet 13* also gives background information about teachers' responses to the 'Energy and Change' project.

Also in this activity, teachers consider the 'dimensions of analysis' used in the research on teachers' transformations (*Activity Resource 3*) and relate these to their own experience and to the case study work. These dimensions relate to the work on all of the curriculum innovations studied by STTIS. *Briefing Sheet 12 'Dimensions of analysis'* reproduces the information in the activity sheet, adding examples about the energy innovations.

## *Notes on Section K  Innovation and transformation*

The main aims of this section are:

- To reconsider the 'stories' about transformations in the light of their further experiences.
- To build on work already undertaken in planning a single lesson to consider how to extend the approach to sequences of lessons.

Notes on the activity follow:

*K1  Review and further planning*

In this activity, teachers look back on the experiences that they have had in the two workshops and their trial lesson, and reflect on what they have learned and how their ideas and beliefs have changed (or not). They also look to the future and consider how to begin to use the ideas in longer term planning. This, of course, can only be a start of the process, as there is much work to be done here in thinking about how schemes of work could be changed to incorporate the new ideas; however, it is a useful point at the end of the workshop to begin to think about this process and to share with others the challenges that they think this will bring.

## *Resources*

The following are lists of the additional resources intended for trainers (the Briefing Sheets) and teachers (Activity Resources). These are available as downloadable documents.

*Trainers’ Briefing Sheets*

- BS1 About the STTIS project
- BS2 Transferring vs Transforming energy
- BS3 Energy – why learn about it?
- BS4 Introduction to ‘Energy and Change’ materials
- BS5 The STTIS research into energy transfer and the direction of change
- BS6 Pupils’ understanding: Insulation
- BS7 Pupils’ understanding: Things that ‘just happen’ and things that don’t
- BS8 Pupils’ understanding: Fuels and food
- BS9 ‘Energy transfer’ and science textbooks
- BS10 ‘Energy transfer’: case study commentary
- BS11 ‘Energy and Change’: case study commentary
- BS12 Dimensions of analysis
- BS13 Teachers’ reactions to ‘Energy and Change’ materials
- BS14 Summary of research on teachers’ transformations

*Activity Resources*

- AR1 ‘Energy transfer’: case studies
- AR2 ‘Energy and Change’: case study
- AR3 Transformations of curriculum innovation: dimensions of analysis

## Science Teacher Training in an Information Society (STTIS)

## Teacher Workshop (UK)

# Teaching about energy

## Briefing Sheets

***Briefing Sheet 1***

# About the STTIS project

The project Science Teacher Training in an Information Society (STTIS) is a research project funded by the European Commission, Directorate General Research within the TSER programme. Five European Universities are involved in a common research where objective and tasks are shared: Denis-Diderot, ParisVII, Federico II da Napoli, Oslo, Autònoma de Barcelona, and Sussex (STTIS, 1998).

## *The issues*

The project deals with general questions and challenges that the present situation of the Information Society poses to science educators. They can be summarised as:

*Information has to be understood*

Science teachers need to have updated knowledge to be able to face with new information. Mastering information requires not only to understand its scientific contents but also to be able to deal with many types and sources of information and to become agile in adapting to and incorporating innovation. Messages (spoken, visual or written) displayed in many different ways (through texts, schemas, drawing, graphs, etc.) should be well understood.

*Information to be taught has changed*

During recent years, changes in the curriculum are common in many countries as a result of social requirements. Science teachers have to incorporate into their courses new elements coming from the results of education researches, from the use of new ways to receive and send information, from new hypothesis about learning and processing information.

*Information is always transformed by the receiver.*

Communications are not simply 'received' but are re-made, re-constituted, and transformed by the receiver. The act of understanding is always transformative, as information is selected, prioritised, interpreted, and decisions based on it are taken and acted upon. In the case of information offered to teachers, the processes of selection and interpretation may have important consequences.

When teachers are faced with curriculum innovations (new teaching strategies, new codes or images to represent some ideas, new informatic tools), they incorporate and adopt information at the same time as some transformation processes are going on. The teacher is necessarily an agent who mediates between innovation designers and students. It is not enough to propose new materials or new tools to renovate science teaching; transformations that can be foreseen should be anticipated.

*Information means have to be mastered.*

Many new didactical sources are offered with informatic support; mastering computer-based tools representing and transmitting information is essential. As well a becoming competent in using different technologies (e.g. various software, internet communications, etc.), teachers need to understand the different ways to present messages and be able to read the information given in a message.

### *The research*

In this general scenario, four related areas of research have been defined for the project STTIS:

- Nature of the use made by science teachers of informatic tools: teachers’ transformations when 'adopting' informatic tools in science classes.
- Difficulties in teaching and learning symbolic representations: teachers’ transformations when 'adopting' symbolic representations.
- Implementing new teaching strategies on some specific contents: teachers’ transformations when 'adopting' innovative teaching strategies.
- Transversal study of teachers' transformations when assuming innovations. Inferring general rules of transformation from the results of the preceding sections and identifying factors that determine the way innovations are interpreted.

The outcomes of the different pieces of research will be applied to the design of new teaching materials for trainers of in-service teachers.

### *The UK contribution*

STTIS research in the UK falls within the following three distinct but related areas:

- the nature of the use made by science teachers of computational modelling tools;
- the difficulties involved in teaching and learning graphic representations such as the ones that appear in popular science textbooks on the topic of energy;
- the transformations which occur when teachers implement innovative strategies related to the teaching of energy.

Building on the findings of these researches, two sets of materials have been developed for training teachers in the use of innovations: one of them is concerned with the use of computational modelling and simulation, and the other with the teaching of energy transfer and the direction of change.

## References

STTIS Consortium (1998) *Outline and justification of research methodology: work packages WP1, WP2 and WP3*, STTIS (Science Teacher Training in an Information Society) Report, European Commission DG XII - TSER: CT97 2020 (co-ord.: R. Pintó, Universitat Autónoma de Barcelona), Synthesis of report: Ogborn, J. and Stylianidou, F., University of Sussex, Institute of Education, UK.

***Briefing Sheet 2***

# Transferring vs transforming energy

> *"Pupils describing processes which involve working or heating are encouraged to focus their attention on the forms of energy and the transformations that occur. This emphasis on forms of energy introduces problems. It draws attention away from the easier, more useful and important understanding of energy transfer." (Ellse 1988, p 427)*

This quote appeared in March 1988 in the School Science Review and echoed the debate at that time amongst science educators in the UK. The issue concerned the replacement of the concept of *energy transformation* used until then by many examination syllabi and textbooks by what was argued to be the more scientifically appropriate and useful concept of *energy transfer*. This debate took place in the context of the amendments performed on the last drafts of the first Science National Curriculum (NC) for pupils of compulsory school age (5-16 years old) in England and Wales. Furthermore, it alluded to a strong interest in the teaching of energy expressed in the international science education scene during the 1980s and evidenced by the many publications on the issue (e.g. Bliss and Ogborn 1985, Brook and Driver 1984, Driver and Millar 1985, Duit 1984, Marx 1983, Ogborn 1990, Schmid 1982, Sexl 1981, Solomon 1982, 1984, Warren 1982, Watts 1983).

The result of this debate was that the first official publication of the NC (DES 1989) contained a notable change in the relevant recommendation. Whereas the interim report (DES 1987) which had preceded it explicitly stated that

> *"Pupils should understand that energy can be thought of as existing in a number of forms: it can be transferred from one place to another and can be transformed."*

The first NC (and every NC publication since) omitted any references to 'forms of energy' or 'energy transformation' and instead focused on the processes of 'energy transfer'. The wording of this recommendation has had slight alterations in the different revisions of the NC since. The Appendix contains a list of all statements in the most recent edition of the National Curriculum (DfEE/QCA 2000) which refer to energy. This states, for example that in KS3, pupils should be taught:

- 5d the distinction between temperature and heat, and that differences in temperature can lead to transfer of energy
- 5e ways in which energy can be usefully transferred and stored

At KS4, pupils should be taught, for example:

- 5a how insulation is used to reduce transfer of energy from hotter to colder objects
- 5d to calculate power in terms of the rate of working or of transferring energy

Implicit in these recommendations is that energy should be thought of as 'staying the same kind of thing' while it goes / flows / is passed from place / object to place / object. Moreover, it should not be associated with its sources, but with the way it travels. So, there are not different forms of energy, but there are different kinds of transfer - energy is carried in different ways, e.g. energy is transferred by work, heat (thermal energy transfer), electricity, and so on. Having said that there are no 'forms of energy', the distinction between 'potential' and 'kinetic' energy is retained (see also Osborne and Freeman 1989, pp29-44); more specifically, pupils should be taught the quantitative links between kinetic energy, potential energy and work.

This change was justified on the basis that the notion of 'energy transfer' is not only scientifically more correct than this of 'energy transformation', but also gives pupils a more rigorous understanding of energy; an understanding which can be further extended to include ideas dictated by the second law of thermodynamics which is taught only much later in schools.

This need for consistency and long-term coherency in the ideas to be taught was not shared, however, by everybody who commented on the NC change. The response to it, although only documented anecdotally, was diverse. According to Mike Coles (interviewed on June 2, 1998 as part of STTIS research), who was lead officer in the working group for science in the NC at that time, although most people accepted that ‘energy transfer’ is a more straightforward concept, some of them also thought that it might be best to start off teaching younger children about forms of energy and only later, when they are older to tackle the notion of ‘energy transfer’. This view identifies with curriculum developers who maintain that approximate and possibly even wrong definitions of difficult concepts can acceptably be included in a curriculum in order so that their teaching becomes possible across the ability range.

## References


Bliss, J., & Ogborn, J. (1985). Children’s choices of uses of energy. *European Journal of Science Education*, *7*(2), 195-203.

Brook, A., & Driver, R. (1984). *Aspects of secondary students’ understanding of energy: Full report.* Leeds: University of Leeds.

DES (1987) *National Curriculum: Interim report.* London: HMSO.

DES (1989) *Science in the National Curriculum.* London: HMSO.

DfEE/QCA (2000) *The National Curriculum: Handbook for secondary teachers in England (Key stages 3 and 4)*. London: HMSO.

Driver, R., & Millar, R. (Eds). (1985). *Energy matters.* Leeds, UK: Centre for Science and Mathematics Education, University of Leeds.

Duit, R. (1984). Learning the energy concept in school - empirical results from The Philippines and West Germany. *Physics Education*, *19*, 59-66.

Ellse, M. (1988). Transferring not transforming energy. *School Science Review*, *69* (248), 427-437.

Marx, G. (1983). *Entropy in the school.* Budapest: Roland Eötvös Physical Society.

Ogborn, J. (1990). Energy, change, difference and danger. *School Science Review*, *72*(259), 81-85.

Osborne, J., & Freeman, J. (1989). *Teaching Physics: a guide for the non-specialist.* Cambridge: Cambridge University Press.

Schmid, G. B. (1982). Energy and its carriers. *Physics Education*, *17*(5), 212-218.

Sexl, R. U. (1981). Some observations concerning the teaching of the energy concept. *European Journal of Science Education*, *3*(3), 285-289.

Solomon, J. (1982). How children learn about energy or does the first law come first? *School Science Review*, *63*(224), 415-422.

Solomon, J. (1984) ‘Prompts, cues and discrimination: the utilisation of two separate knowledge systems’, *European Journal of Science Education*, 6, 3, 277-284.

# Appendix: Energy in the National Curriculum

This briefing sheet identifies those statements relating to energy which appear in the National Curriculum for England for Key Stages 3 and 4

Source: DfEE/QCA (2000) *The National Curriculum: Handbook for secondary teachers in England (Key stages 3 and 4).* London: HMSO.

## Key stage 3

### *Sc3 Materials and their properties: Changing materials*

*Physical changes*

2c) to relate changes of state to energy transfers

### *Sc4 Physical processes: Electricity and magnetism*

*Circuits*

1c) that energy is transferred from batteries and other sources to other components in electrical circuits

### *Sc4 Physical processes: Energy resources and energy transfer*

*Energy resources*

5a) about the variety of energy resources, including oil, gas, coal, biomass, food, wind, waves and batteries, and the distinction between renewable and non-renewable resources

5b) about the Sun as the ultimate source of most of the Earth's energy resources and to relate this to how coal, oil and gas are formed

5c) that electricity is generated by means of a variety of energy resources

*Conservation of energy*

5d) the distinction between temperature and heat, and that differences in temperature can lead to transfer of energy

5e) ways in which energy can be usefully transferred and stored

5f) how energy is transferred by the movement of particles in conduction, convection and evaporation, and that energy is transferred directly by radiation

5g) that although energy is always conserved, it may be dissipated, reducing its availability as a resource.

## KS4: single science

### *Sc3 Materials and their properties: Patterns of behaviour*

*Rates of reaction*

3j) how the rates of many reactions depend on the frequency and energy of collisions between particles

### *Sc4 Physical processes: Electricity*

*Mains electricity*

1h) how measurements of energy transferred are used to calculate the costs of using common domestic appliances.

### *Sc4 Physical processes: Energy resources and energy transfer*

*Energy transfer*

4a) how insulation is used to reduce transfer of energy from hotter to colder objects

4b) about the efficient use of energy, the need for economical use of energy resources, and the environmental implications of generating energy

*Electromagnetic effects*

4c) how simple ac generators work

4d) how energy is transferred from power stations to consumers.

## KS 4: double science

### *Sc2 Life processes and living things: Living things in their environment*

*Energy and nutrient transfer*

5e) how energy is transferred through an ecosystem

5g) how food production and distribution systems can be managed to improve the efficiency of energy transfers.

### *Sc3 Materials and their properties: Patterns of behaviour*

*Rates of reaction*

3p) how the rates of many reactions depend on the frequency and energy of collisions between particles

*Energy transfer in reactions*

3t) that changes of temperature often accompany reactions

3u) that reactions can be exothermic or endothermic

3v) how making and breaking chemical bonds in chemical reactions involves energy transfers.

## *Sc4 Physical processes: Electricity*

*Circuits*

1e) that voltage is the energy transferred per unit charge

*Mains electricity*

1j) how measurements of energy transferred are used to calculate the costs of using common domestic appliances

## *Sc4 Physical processes: Waves*

*Characteristics of waves*

3d) that waves transfer energy without transferring matter

Sc4 Physical processes: Energy resources and energy transfer

*Energy transfer*

5a) how insulation is used to reduce transfer of energy from hotter to colder objects

5b) about the efficient use of energy, the need for economical use of energy resources, and the environmental implications of generating energy

*Work, power and energy*

5c) the quantitative relationship between force and work

5d) to calculate power in terms of the rate of working or of transferring energy

5e) to calculate kinetic energy and potential energy

*Electromagnetic effects*

5j) how energy is transferred from power stations to consumers.

# Attainment targets

## *Attainment target 3: materials and their properties*

*Level 6*

They relate changes of state to energy transfers in a range of contexts [for example, the formation of igneous rocks].

## *Attainment target 4: physical processes*

*Level 6*

They use abstract ideas in some descriptions and explanations [for example, electric current as a way of transferring energy, the sum of several forces determining changes in the direction or the speed of movement of an object, wind and waves as energy resources available for use].

They recognise, and can give examples of, the wide application of many physical concepts [for example, the transfer of energy by light, sound or electricity, the refraction and dispersion of light].

*Level 7*

They apply abstract ideas in explanations of a range of physical phenomena [for example, the appearance of objects in different colours of light, the relationship between the frequency of vibration and the pitch of a sound, the role of gravitational attraction in determining the motion of bodies in the solar system, the dissipation of energy during energy transfers].

*Level 8*

They consider physical phenomena from different perspectives [for example, relating the dissipation of energy during energy transfer to the need to conserve limited energy resources].

*Exceptional performance*

They recognise the importance of quantitative data and make effective use of this when they consider questions such as energy efficiency.

***Briefing Sheet 3***

# Energy - why learn about it?

## What makes things happen?

The word 'energy' is commonly used in an everyday sense (and often in school science courses and books) to explain what makes things happen - 'the battery in the torch makes the bulb light because it has energy'. However, used in its scientific sense energy is *not* what causes change - things change because *differences disappear* (or entropy increases) which means that energy or matter or both become more spread out and less concentrated.

If energy is not the cause of change and does not make things happen, then what role can in have in learning about science? Think about the following questions:

- If you put a burning match under a saucepan of cold water, would it boil?
- If you put an ice cube under a saucepan of cold water, would it boil?

The answer to both questions is no, but for different reasons. In the first case, the match will heat the water up but not enough to make it boil. In the second case, the ice cube makes the water colder not hotter.

So, in the first case the impossibility is a question about *amounts*. Energy is transferred from the burning match to the water, but more energy needs to be transferred in order for it to boil. This *quantitative* aspect is an essential part of learning about energy. It should involve comparisons of the amounts of energy transferred from and to various kinds of systems - for example, the amounts of energy transferred from burning fuels, from engines, from power stations, from torch batteries and the amounts of energy transferred to things being heated, to electrical appliances, to the surface of the Earth from the Sun, and so on.

In the second case, the impossibility is a question about the *direction of change*. Energy flows from the cold water to the ice cube and not the other way. The reason lies in the *concentration of energy*. Energy is transferred from where it is concentrated to where it is less concentrated.

## Energy transfer

The National Curriculum refers to energy *transfers*, and makes no mention of talking about energy as being changed from one form to another (e.g. chemical to electrical). This is significant since it stresses the importance of thinking about energy as *staying the same kind of thing* but in *going from place to place*. However, the term 'energy transfer' is simply a label for an idea - because the term appears in the National Curriculum does not mean that we are obliged to use it exclusively. What we should be doing is encouraging pupils to feel comfortable with rather more informal ways of expressing this idea. So, as well as:

- 'energy is transferred from X to Y'

we can say

- 'the energy is going from here to there'
- 'the energy is spreading out'
- 'energy flows from the hot thing to the cold thing'
- 'energy is travelling from one place to another'
- 'the energy is concentrated here at the start, but some of it ends up there'.

## Some questions about scientific ideas

*What is a thermodynamic change?*

In mechanics, bodies behave (almost) like single particles, despite being made of molecules. All the molecules share a common movement or change of position. To a good approximation, the internal energy of the bodies does not change. But as soon as there is dissipation, we are doing thermodynamics. A perfectly bouncy ball is mechanics; a waterfall is thermodynamics. In general, we are in thermodynamics when changes in the arrangements of molecules and their energy have to be taken into account.

*What is the Second Law of Thermodynamics?*

If you have some old socks in one corner of a room, you will eventually smell them if you stand in the other corner. Why? Because molecules move around randomly. So the air molecules and the smelly molecules from the socks mix together. Arrangements of molecules tend to become *disordered*. A similar thing happens with energy. Essentially, what the Second Law says is that at the molecular level *things tend to get jumbled up or disordered*.

Talking about 'disorder' can be potentially confusing with pupils. What we *observe* is that *differences* tend towards *sameness*. A drop of ink put in water produces swirling patterns of colour. After a while the colour will be spread throughout the water. So, the *differences* in the concentration of ink will all disappear and become the *same*. A pupil may think that we should say it has become *more ordered* - it goes from 'untidy' swirls to a tidy' even colour - but it is at the *molecular* level that it has become *more disordered*.

The Second Law provides 'time's arrow'. We can often tell when a film is played backwards - a broken cup does not spontaneously assemble itself and waterfalls do not flow upwards.

*What is entropy?*

Entropy is a measure of how disordered a system is at the molecular level. Since disorder tends to increase, another way of putting the Second Law is that in a spontaneous process entropy increases. Entropy sounds a mysterious idea to many people, but it can be easily measured and calculated - its units are J/K (joules per degree Kelvin). However, with pupils it makes more sense to talk about *differences tending to disappear* than to talk about *entropy increasing*.

*What is the first Law of Thermodynamics?*

Historically, the First Law was formulated after the Second Law. It can be thought of as being the Law of Conservation of Energy - that energy is neither created nor destroyed.

More accurately, it says that the energy of a system changes when energy goes into or out of it, and that it doesn't matter how the energy is made to go in or out. It could be changed by heating it or by doing work on it, and these are equivalent - energy is energy.

What the First Law does is to put a constraint on the possible states of a system. A litre of paraffin can be burnt to boil up some water. The energy transferred from the paraffin will always be the same - the rate at which you burn it or the size of the wick will not affect the amount of energy.

*What is energy?*

One way of thinking of energy is simply as a value which can be calculated. Many different kinds of change take place - a candle burning, a ball rolling downhill, an electric kettle boiling some water - but for each of these you can calculate the total energy before and find that it is the same as the total energy after. We could think of this as a 'book-keeping' approach.

Another approach is to think of energy as 'substance-like'. So, we can talk of energy as being in a certain region, moving from one place to another, having a lot of it or a little of it, making it concentrated in one region or letting it spread out. Temperature can be seen as being a measure of the 'concentration of energy', and energy is what flows when temperature differences disappear. This is the approach taken in the introduction to the ‘Energy and Change’ materials. The approach is then extended to other kinds of changes involving energy.

*If everything tends to sameness, how can anything ever be created?*

If differences only decreased, life would not be very interesting. In fact there would be no life. It is possible to *create* differences - we can make cups of tea hot, and we can make big molecules from small ones. But we can only do this by *using up other differences*.

For example, water vapour condenses on a cold window. This seems to go against what we said about matter tending to spread out. Here it is being concentrated in a small space - *a concentration difference is appearing*. But *a temperature difference is disappearing* - the water is now the same temperature as the window. A little bit of order has been created in one part of the Universe, but more disorder has appeared somewhere else. Overall, the change is of increasing disorder.

*But surely the Second Law cannot apply to living things?*

The Second Law is *universal*. Our own bodies are bound by it. When our bodies make some protein molecules to repair a cut or we put some books back on the bookshelf, we are creating a little bit of order. But overall we create more disorder - always we are 'burning' food, and energy spreads out from our warm bodies into the cooler air around us. People sometimes misinterpret the Second Law in relation to living things, thinking that the law is somehow 'suspended' until death, when the organism 'obeys' the law as it decays. Living things *constantly* create structures, and so they must *constantly* consume differences.

## Some questions about teaching and learning

*Is energy the cause of change?*

No. School science books often suggest that energy is what makes things happen, but they are wrong. It is *differences* that cause change. So, a flame heats a saucepan on water. This does not happen because the flame 'has a lot of energy', but because the flame is hotter than the water (a temperature difference).

*If energy does not cause change, can there be changes where energy is not involved?*

Certainly. Pollution from a factory spreads out into the air. Energy is not involved in this process. It happens because of a concentration difference.

*Isn't heat a form of energy?*

Heat is a term which causes a lot of argument about the way it is used at school level. Strictly speaking, heat is the energy transferred from one body to another due to a temperature difference. It is not the energy contained in a body. What is usually referred to as the heat energy in a body is more correctly referred to as its internal energy. So, if you rub your finger on the table it gets hotter, but you are *not* creating heat. You are increasing the internal energy of your finger and the table by doing work. Because your finger and the table are now warmer, heat may pass from these to the cooler surroundings.

We have avoided talking about heat flow - it is simpler just to say that when a flame makes a beaker of water hot, energy has flowed from the flame to the water. This is helpful in that it reinforces the idea of changes in the arrangement of energy and matter being caused by differences (here a temperature difference).

*Why not teach about forms of energy?*

Much of the talk involving forms of energy is no more than adding verbal ornamentation to descriptions of changes. We can say that burning petrol in an engine makes a car move. We hardly gain any deeper understanding calling this a change of chemical energy to kinetic energy. Pupils do not always find it easy to find the correct labels to attach to these energy changes and often invent their own. So, a child taking part in a race might be seen as converting 'food energy to running energy'. Textbooks, as well as children, also show variations in the terms used for 'forms or energy', which complicates things further.

Further difficulties are introduced in some books, which try to associate a 'form of energy' with an object which illustrates it. For example, a can of petrol may be used to illustrate 'chemical energy', or a battery to illustrate 'electrical energy'. This is inconsistent. Why not make a can of petrol an example of 'heat energy' and a battery an example of 'chemical energy'?

In more advanced work, students will find that there are different ways of making calculations depending on the kinds of energy change involved. At this point, we may be more justified in talking about 'forms of energy'.

*Why does the National Curriculum talk about energy transfers?*

The difficulties with the 'forms of energy' approach have led the National Curriculum to refer throughout to 'energy transfers'. While the change in terminology from 'transformation' to 'transfer' seems slight, it actually signifies a fundamental change. Talking about energy transfer stresses the importance of thinking about energy as *staying the same kind of thing* but in *going from place to place*, which is the approach taken in this booklet. Often, however, the significance of the new terminology has gone unnoticed, with patent nonsense such as 'chemical energy *transferred* to heat energy'.

*What ideas about energy do pupils bring to the classroom?*

In everyday talk, we say that we do, or do not, have the energy to do something. Much research into children's ideas about energy indicates that this is their starting point: that energy is associated with activity and being alive, that it represents a power to act, that it is used up. Quite correctly, children see that taking exercise can make one more energetic, not less. They may see food, not as providing energy but as triggering energy production by the body. In school textbooks, the use of the term 'energy' often slides between two contradictory meanings - as something which is used up (reinforcing the everyday meaning) and as something conserved (which pupils find difficult to reconcile with their own understanding of energy).

*What do pupils understand about particulate theory?*

An understanding that matter is made of particles is essential to understanding the nature of a substance and of chemical reactions. If change is merely a re-arrangement of particles, mass must be conserved. However, young pupils often think, for example, that a solution will weigh less than the liquid and solid before dissolving, since the solid has disappeared. They are more likely to believe that mass is conserved if they see dissolving as a mixing of particles. In trying to make sense of particulate theory, many pupils come to think that substances *contain* rather than *consist* of particles. For example, when a liquid freezes, the particles moving around *in* the liquid stop moving because they are now trapped *in* a solid. Another common difficulty is the tendency to project from a macroscopic phenomenon to the microscopic behaviour of particles, for example, a solid expands when heated because the particles of the solid become bigger.

***Briefing Sheet 4***

# Introduction to 'Energy and Change' materials

> *"Shoe leather wears out because it rubs against the sidewalk and the little notches and bumps on the sidewalk grab pieces and pull them off. That is knowledge. To simply say, 'It is because of friction,' is sad, because it's not science."*
> Richard Feynman (quoted in 'Genius' by James Gleick)

'Energy and change' is a set of materials (Boohan and Ogborn, 1996a; Boohan 1996a) which addresses the fundamental question 'why do things change?'. It does this not simply by labelling phenomena with words to explain them away, but by looking at the essential nature of physical, chemical and biological changes. Our aim is to provide a coherent framework within which many important scientific concepts can be developed.

The key idea in our approach is to pay attention to the differences which drive change (Ogborn, 1990). For example, air in a balloon tends to leak out because of a *pressure difference* - it continues to spread out until the pressure difference disappears. Pollution spreads out and mixes with the air in the atmosphere because of a *concentration difference*. Eventually the concentration difference disappears. Hot coffee cools because of a *temperature difference*. Energy spreads out into the surroundings, as it goes from hot to cold, until eventually the temperature difference disappears. Thus, differences tend to disappear because matter or energy or both become more spread out. This essentially simple idea is also powerful. We can use it to make sense of a wide range of phenomena from a hot cup of tea cooling, to the direction of chemical reactions and even to the complexity of life.

Many differences are expensive to obtain and may be able to do something for us. A frozen ice cube has to be specially made and can cool a drink. Pure water has to be specially provided and is important for life. Differences must be maintained if they are to be useful, and this may be difficult - ice easily melts, water easily becomes polluted.

How can we make differences? The hot water for the coffee was made hot by a hotter flame. Pure water can be made by distilling it, using a hot flame. Behind this is the idea that it takes a (bigger) difference to make a difference. Fuels are valuable because they can create a difference which drives a desirable change, such as heating a house or driving an engine. A difference is being used up to create another difference.

Warm rooms, plants or animals are all kept as they are, far from balance with the environment, by a heater, by sunlight, or by food. They do it by continually consuming differences, so as to maintain themselves. By being away from equilibrium they themselves constitute a difference which can cause other changes, as when we run around or when a flame heats a kettle.

An understanding of why things change is clearly of fundamental importance in science. How is it currently taught in schools? 'Energy is what makes things happen' is a fairly typical statement which could be found in many school science textbooks. It sounds plausible, but it is wrong, and has led to much confusion. A flame heats a pan of water, not because the flame 'has a lot of energy', but because the energy in the flame is more concentrated than the energy in the water (i.e. it is hotter). It is this difference which drives the flow of energy.

In addition, the focus in most school textbooks has been on learning about 'forms of energy'. But to say that a car engine converts chemical energy in petrol to kinetic energy adds little to our understanding of the fundamental nature of the change (in the same way that saying friction makes shoes wear out attaches a word to the phenomenon but does not explain it). And while electric fires are said to 'convert electrical energy to heat energy', what do fridges do? We cannot say they convert electrical energy into 'cold energy'! A 'differences' approach accounts for such changes more easily - electric fires and fridges create temperature differences which do not arise by themselves, but are created by a difference being used up in a power station.

The National Curriculum does not refer to 'forms of energy' but instead talks in terms of 'energy transfer', in which the focus is on what happens to energy, where it is at the start and at the end, how it moves from one place to another, and so on. The terminology adopted by the National Curriculum is consistent with the idea of energy flows being driven by differences.

It should be clear from the above account that our approach to teaching about why things change is not something which can be confined to a topic called 'energy'. The activities we have developed can be used in many areas of the science curriculum. They form the basis of a consistent story about processes of change which can be developed across the whole age range. Here are a few examples of areas in which these ideas could be used:

dissolving
pollution
evaporation
separating and purifying mixtures
chemical change in everyday materials
meaning of hot and cold
energy transfers
weather and the water cycle
burning fuel and the release of energy
energy resources
photosynthesis
respiration
energy efficiency
weathering of buildings and rocks
metal extraction and corrosion
microbes and decay
cost of energy used by domestic appliances
cycling of materials in ecosystems
energy transfers in ecosystems
the atmosphere
maintaining the internal environment of plants and animals
enzymes and the synthesis of biological molecules

In understanding such a wide range of different kinds of processes, we will need to help pupils see that many changes are essentially similar, even though, superficially, they appear to be very different. Thus, dissolving is rather like evaporation in that particles spread out, though there are also important differences. Respiration is in some ways like burning. A human being can be understood as being a 'steady state system' rather like a central heating system.

Making such abstractions is not easy, so we have developed a range of pictorial representations to help pupils to do this. A discussion of these abstract pictures and examples of their use can be found in Boohan (1996b), and Boohan and Ogborn (1996b). In the activities in this workshop, a selection of these abstract pictures have been used, the emphasis being on energy flows due to temperature differences and energy changes in chemical reactions.

## References

Boohan, R. (1996a) *'Energy and Change: Support materials'* (Institute of Education, University of London).

Boohan, R. (1996b) 'Using a picture language to teach about processes of change' in Welford, G., Osborne, J. & Scott, P. (eds) (1996) *Research in Science Education in Europe* (The Falmer Press), 85-89.

Boohan, R. & Ogborn, J. (1996a) *'Energy and Change'* A set of three booklets, (Association for Science Education, Hatfield, England).

Boohan, R and Ogborn, J (1996b) Differences, energy and change: a simple approach through pictures. *School Science Review, 78*(283), 13-19.

Ogborn, J. (1990). Energy, change, difference and danger. *School Science Review*, *72*(259), 81-85.

***Briefing Sheet 5***

# The STTIS research into energy transfer and the direction of change

It is our starting point that teachers' interpretation of a proposed teaching sequence may result in transformations of the original didactic intentions. The research discussed here concerns two different kinds of curriculum innovations and their transformations by teachers (Stylianidou and Ogborn, 1999). One is the change in the National Curriculum from 'transforming' to 'transferring' energy and the other is the smaller scale innovation introduced by the curriculum materials developed by the 'Energy and Change' project. For each of these two curriculum innovations we first identified the types of actions that ensue from the didactic intentions of the innovations and then we looked for their existence, absence or transformation through teacher case studies.

## Energy transfer

The change in the National Curriculum from 'transforming' to 'transferring' energy first appeared in the recommendations concerning the teaching of energy of the 1989 Science National Curriculum for England and Wales. Ten years after this change the questions posed by the research were:

- How is the change in the National Curriculum reflected in the textbooks used in the science classroom?
- How are the recommendations of the National Curriculum about the teaching of 'energy transfer' understood (by student teachers)?
- How are these recommendations put into practice in teaching?

We first looked at whether and how the new National Curriculum recommendations on 'energy transfer' were realised in the science textbooks. This is because we perceive the textbooks as being one of the key actors in the translation into actual teaching practice of this kind of innovation, which was prescriptive, but nevertheless not well defined or explained to the people who were meant to implement it.

We also investigated how the written recommendations concerning the teaching of energy are understood by student teachers of science. Five trainee teachers, who had previously attended a university training session on the teaching of 'energy', were interviewed on their understanding of these recommendations. Another four teachers were observed introducing the topic 'energy' to their classes and were interviewed afterwards about it. Observation records were kept from their lessons, and in some cases pupils' work was collected.

The two groups of teachers were analysed as case studies, but were treated separately, as different sets of data were collected from them. The foci of the analyses were complementary; in both sets of data we looked for the following occurrences:

- for exclusive and strict uses of the 'energy transfer' idea;
- for exclusive and strict uses of the 'energy transformation' idea;
- for uses of 'energy transfer' to mean 'energy transformation';
- for specialisation of the 'energy transfer / transformation' uses to energy types or levels of schooling;
- for post-hoc rationalisation of the issue;
- for instances where awareness of the issue lead to self-correction.

The findings seem to indicate that the intentions of the innovators of the National Curriculum may not be fulfilled in today's teaching of energy. The teachers in theses case studies accommodated the new nomenclature to their existing schemas. Their underlying conceptions did not alter, only the terms they used to express them. A similar finding also emerged in the analysis of the science textbooks. Almost a quarter of the post-NC textbooks makes use of the ‘energy transfer’ idea to convey little more than the idea of ‘energy transformation’.

## Energy and change

The ‘Energy and Change’ project aimed to provide novel ways of teaching about the nature and direction of changes, introducing ideas related to the Second Law of Thermodynamics. The research questions, as with the National Curriculum innovation, concerned the teachers’ use of the innovatory approach:

- How have teachers used the novel aspects of the approach suggested by the ‘Energy and Change’ curriculum materials in their classroom?
- How have teachers incorporated this approach in their schemes of work?

We used two sources of information. An evaluation of the learning outcomes of the new teaching approach earlier conducted and reported elsewhere (e.g. see Stylianidou 1997, Stylianidou and Boohan 1998) provided us with the case studies of two teachers who had used the new materials with their classes over a period of eight months. For the STTIS research, data were collected from two schools and were treated as case studies. In the first school, a physics teacher who had made spontaneous use of the innovative project materials and had diffused the ideas to other physics teachers in the school, was observed using the project materials, and was subsequently interviewed. In the second school we attended an In-Service Training session in which the ‘Energy and Change’ approach and curriculum materials were presented to 13 teachers from the locality. An evaluation questionnaire was given out to them at the end of the session. One teacher from this group, was subsequently observed using the approach for the teaching of the topic ‘Energy’ to 11-12 year-old pupils, in the course of five weeks.

All four case studies of teachers using of the ‘Energy and Change’ materials were then interrogated with the above research questions. However, the different contexts in which the materials were used made that some case studies could more readily address one or the other of the research questions.

The results of the research show that the ‘Energy and Change’ innovation was transformed and adapted in each case to the school’s ethos, to the teachers’ pattern of work and to what the teachers already knew. The innovation is not prescriptive but provides teachers with curriculum materials and a general framework for their use, which means that it is open to a number of different kinds of transformation. Transformations may arise from the adoption of an innovation at the microscopic scale, which is the context of the teacher’s classroom, but also those arising at the macroscopic scale, which is the context of a whole school.

## References

Stylianidou, F. (1997) ‘Children’s learning about energy and processes of change’, *School Science Review*, *78*(286), 91-97.

Stylianidou, F. and Boohan, R. (1998) ‘Understanding Why Things Happen: Case-Studies of Pupils Using an Abstract Picture Language to Represent the Nature of Changes’, *Research in Science Education*, *28*(4), 447-462.

Stylianidou, F and Ogborn J (1999) Teachers’ transformations of innovations: the case of teaching ‘Energy’ in English secondary schools, STTIS (Science Teacher Training in an Information Society) UK National Report on Work Package 3, European Commission DG XII - TSER: CT97 2020 (co-ordinator: R. Pintó, Universitat Autónoma de Barcelona), (University of Sussex, Institute of Education)

***Briefing Sheet 6***

# Pupils' understanding: Insulation

This briefing sheet provides a commentary on the examples of pupils' discussion given in Activity B5.

Children often tend to see insulation as something which actively keeps or makes things hot, and think of 'cold' as well as 'heat' as being something that flows from one place to another. The abstract pictures in this activity aim to encourage children to start thinking of insulation as a barrier to energy flow from a higher to a lower temperature. The activity has been used with a number of different Y8 groups. Nearly all pupils were able to use the abstract pictures to make matches which they could justify with a reasonable explanation. Even though some children did not differentiate the meanings of heat, energy and temperature, they still attempted to think in terms of *differences* and *flows*.

> *"The hot chocolate is hotter than the room temperature ... and when the hot chocolate is left in the room, 'cos the room is colder the energy goes out of it and the hot chocolate starts to get cold slowly."*

> *"Because the frozen food left on the table and the food is colder than the room and the room temperature melts the frozen food ... the energy is going into the food and makes it warmer."*

Explanations in which concepts are not differentiated can be useful starting points for teachers to discuss with pupils:

> *"The food is more colder so the room temperature will go into the food and the newspaper is not that powerful so the room temperature will slowly go into the newspaper wrapping the food."*

A number of pupils managed quite sophisticated explanations, referring explicitly to the pictures. Here, a pupil is explaining what happens to a hot chocolate drink in a cup and in a thermos flask:

> *"The hot chocolate is hotter than the room temperature so this* (the central region in the representation) *is darker* (i.e. hotter with energy more concentrated) *and when the hot chocolate is left in the room, because the room is colder the energy goes out of it* (the chocolate) *and the hot chocolate starts to get colder slowly. This one in here* (in the vacuum flask) - *the hot chocolate is still hotter than the room so it's darker but it stays the same, as it's in the vacuum flask so no heat will come out and no heat will come in."*

Supported by these abstract pictures, many pupils were able to give extended explanations like this. Differences in choices of representations can also provoke fundamental discussion, here about whether heat and cold are two things or just aspects of one thing:

> One choice of picture:
> *"It's colder on the inside, and then the energy from the heat on the outside is going in making it warmer, and when it's in the vacuum flask the coldness just escapes making it warmer."*
> A different choice of picture:
> *"Mine's the same really but the cold doesn't escape - the insulation makes the lemonade warmer."*
> *"That's what I meant - the insulation makes it warmer."*
> *"No but that means if the insulation made it warmer the cold wouldn't go out but the heat would come in - so the heat goes in not comes out."*

Using the abstract pictures appeared to encourage pupils to pay attention in their explanations to important features of these situations, such as temperature differences and energy flows.

***Briefing Sheet 7***

# Pupils' understanding: Things that 'just happen' and things that don't

This briefing sheet provides a commentary on the statements made by pupils given in Activity B6.

This activity introduces pupils to the fundamental notion that spontaneous changes can drive non-spontaneous changes. The situations in the activity are chosen to be as straightforward as possible, in order for pupils to be able to focus on understanding the conventions. Groups of Y9 pupils, over a month after they had done this activity and other activities using similar conventions, were shown some examples of these pictures and asked to explain in their own words what they understood by them.

Pupils had no difficulty in interpreting the picture which shows a hot object spontaneously cooling as energy flows from it to the cooler surroundings.

> *"Something hot losing energy - getting cold."*
>
> *"This is a room and this is a block and it is giving heat to the room and becoming the same temperature as the room."*
>
> *"This happens usually, naturally."*
>
> *"It just happens normally."*

They also had no difficulty in interpreting the reverse change.

> *"It's showing taking energy in."*
>
> *"This is an example right. There is a glass of water and to make it hot just wouldn't happen."*
>
> *"It does happen, but it is difficult to make it happen."*
>
> *"It doesn't happen naturally but people ... You can make it happen."*

On the whole, they were able to interpret the pictures which show objects slowing down and speeding up, though occasionally, a few pupils interpret the 'moving object' symbol as meaning that the object is moved by the action of an agent (the 'wind').

> *"Something that is going fast and then slows down."*
> *"Something starts moving."*
> *"Natural and ... "*
> *"One works - that one - and that one doesn't usually happen."*
> *"Poltergeist!"*
>
> *"Something that is moving and that is slowing down - stopping."*
> *"Could be the wind that is pushing it or it just happens."*

Finally, pupils seem to grasp the essential nature of coupled changes.

> *"This is the argument that it's possible, yeah? So you use something that is possible to make something that is impossible possible!"*

> *"The 'down' one is something that happens and the 'up' one is - someone has to make it happen."*

The idea that changes which 'just happen' can drive those which do not 'just happen' is unfamiliar in school science, and at first the pictures which represent them may seem rather abstract. In fact, pupils pick up the idea quite readily, as the few examples above suggest, and are able to remember them even after a period without using them.

***Briefing Sheet 8***

# Pupils’ understanding: Fuels and food

This briefing sheet provides a commentary on the examples of pupils’ discussion given in Activity B8.

Perhaps the most difficult idea in all of the activities is the notion of a' chemical spring'.  The extracts below are from discussions of Y8 and Y9 pupils doing an activity in which they need to distinguish energy released from hot objects and from 'chemical springs' as well as understanding the idea of changes which 'just happen' and those that do not. Ideally, the pupils would have had much more experience of building up their understanding about the approach over a long period of time.  In fact all of the relevant work on using the abstract pictures had been done in the few weeks before the activity.

The pupils made correct matches in very many of the situations, and were able to give explanations using relevant features of the pictures.  Some situations are rather easier than others to explain, since what is identified as the 'system' is less open to interpretation.  Here, pupils explain correct matches:

> *"Like something happens by itself ... so ... it's from stored to released.*
> *"Because energy was inside and it went outside."  (torch battery)*
>
> *"Because it goes from hot to cold, and it's heat and energy is being released."  (bath cooling)*
>
> *"Because it's stored and then it's released which makes the car move."  (petrol used in a car)*
>
> *"Someone's driving that to get hot."  (light bulb)*
>
> *"Number 6 then, because that's like pulling chemicals and things (6), and this is just cooling down (5)." (person running)*

However, some situations are more complex and are open to different interpretations depending on the features to which pupils pay attention.  Wood burning and photosynthesis are examples of such situations.  Like a torch battery, when wood burns energy is released from a 'chemical spring'.  However, as it burns, the system makes itself hot, and energy also flows into the cooler surroundings, and pupils also pay attention to these features.

> *"It's the wrong picture (2).  That's the release of stored energy.  It is number 1 because it's like going from hot to cold."*
>
> *"That's between hot and cold (1)."*
> *"That's stored energy (2)."*
> *"Can be both but because heat is fire ... so it goes with number one."*
>
> *"Because the energy is stored up and then it's being released and it happens by itself, so I thought it was number two."*
>
> *"Something is making that burn, and like it's getting hotter and energy is being used (3)."*

Most pupils seem aware in their answers that a plant growing is not a change which 'just happens by itself' but is a change which needs to be driven.  However, they may see a plant growing as essentially a change in which an object needs to be moved, rather than one in which a fuel is being made.  So some pupils chose pictures which represented energy from Sun seen as driving change to make something move (5) or energy from food making something move (6).

Pupils were also asked whether there were any similarities between situations that they had matched to the same abstract picture.

> 'an electric light bulb gets hot' and 'using a kettle to boil some water'
> *"Energy is being stored up "*
> *"Something is driving the water, something has to drive the light bulb."*
> *"It doesn't just happen by itself."*

> 'petrol is used in a car engine' and 'a person uses up food running a race'
> *"You gotta put energy in and then take it out - use it, burn it up, in other words."*
> *"That is stored ... "*
> *"That is driving that."*
> *" ... but then it's released.  It's stored then it's released, but then the person's running."*

Using the abstract pictures pupils were able to see more fundamental similarities between different changes than in an earlier activity, in which they had to identify similar changes but without the support of the abstract pictures.

*Briefing Sheet 9*

# 'Energy transfer' and science textbooks

Are the National Curriculum recommendations on 'energy transfer' realised in the science textbooks? Textbooks after all play a considerable influence not only on what children learn, but also on what teachers teach. On many occasions teachers rely heavily on textbooks among other resources for the implementation of the curriculum. In the investigation carried out as part of the STTIS research, 24 science textbooks were chosen; 17 of them were published after 1989, that is after the introduction of the innovation, and seven before, starting from 1966.

The textbooks, and accompanying teachers' guides, were examined for the following:

- exclusive and strict uses of the 'energy transfer' idea;
- exclusive and strict uses of the 'energy transformation' idea;
- uses of both the 'energy transfer' and 'energy transformation' ideas.

## *Use of either 'energy transfer' or 'energy transformation'*

Around half of the textbooks examined adopt exclusively one or the other approach, and from these about half (i.e. a quarter overall) use each. Interestingly there is no significant difference in these proportions after the arrival of the National Curriculum.

Among the textbooks that make use of the 'energy transfer' idea there are those that retain references to potential and kinetic energy, and sometimes also to thermal or radiation energy, and there are those that make no mention whatsoever to any 'forms' of energy. Most of the 'energy transfer' textbooks explicitly acknowledge that there is a difference between the two ways of talking about energy and take a clear position in this debate:

> *"It is more useful to emphasise mechanisms by which energy is transferred from one system to another than different forms of energy, so that electrical conductors, chemical reactions, and pulley systems are all seen as energy-transfer mechanisms."* (Bausor et al, 1974, p11)

> *"The idea that energy is transformed when it is transferred leads pupils to think that the energy associated with different things (chemicals, electricity, motion, hotness) is essentially different. This tends to make energy seem a material substance, rather than a quality of a system ('having energy') which, like temperature for example can change according to the circumstances. Consequently, there is not mention of the idea of energy transformation or of 'forms of energy' in the course."* (Nuffield, 1993, p30)

On the other hand, there are the 'energy transformation' textbooks. These make clear references to 'forms of energy' and talk about converting or changing energy from one form to others. The number of forms of energy they name vary from six to eight. The names they give for them vary as well though not considerably; the 'standard' energy forms mentioned are: light, sound, electrical, chemical, heat (or internal), potential (also stored, up-hill, or springs energy), kinetic (or moving) energy and nuclear energy. From the 'energy transformation' textbooks only one seems to acknowledge that

> *"...there is some dispute among science teachers over whether the notion of forms of energy should be used at all. This book uses the 'forms' approach, while recognising that it can be problematic."*
> (Garrick, 1991, p101)

## *Use of both 'energy transfer' and 'energy transformation'*

Textbooks that use ideas both of 'energy transfer' and of 'energy transformation' account for almost half of the textbooks investigated, both before and after 1989. They appear to be divided in two kinds.

**Textbooks emphasising 'changes' of energy**

All pre-NC science textbooks examined which make use of both 'energy transformation' and 'energy transfer' ideas are of this kind. The emphasis is put on the 'changes' of energy and this is expressed explicitly and unequivocally; the 'energy transfer' idea is also present as an added idea which is used either infrequently or alongside the 'energy transformation' approach but not in an overtly contradictory way. In the following extract for example, taken from the 'General Introduction' book of the Revised Nuffield Physics (Nuffield 1966, 1977) textbook series, although the expressions [energy] 'transfer' and [energy] 'conversion from one form to another' are used as synonyms, it is also made clear and explicit that they are both meant to deal with 'changes' of energy:

> *"If this emphasis on* transfer *or conversion from one form to another makes us seem to deal only with* changes *of energy, we ought not to be sorry - since that gives a strong reminder of conservation."* (p30)

Another example comes from the textbook 'Science Companions' (Porter et al, 1991). The book clearly talks about 'different kinds of energy' and energy 'changing' from one form to another, but it also has a section on 'belts' and 'gears' and there the talk is about energy being transferred from one place or object to another; e.g. for a bicycle, it is said that

> *"The chain on the bicycle can transfer the energy that legs give the pedals to the back wheel."* (pp78-79)

**Combining 'transfer' and 'transformation'**

After the introduction of the NC, a different kind of combination of the two ideas appears in some science textbooks. The emphasis in these is said to be on the transfer of energy. However, this approach is not seen as incompatible with the use of forms of energy. On the contrary, it is combined with it, so that energy is said to 'transfer from one form into another'. In other words, whereas terms related to the 'energy transfer' idea appear prominently in the textbook, these are used to convey little more than the idea of 'energy transformation'. The following extract exemplifies this contradictory use:

> *"Energy is transferred from one form to another. Chemical energy in the food is transferred to chemical energy in your body, which is transferred to the uphill energy in the brick. If the brick is then allowed to fall, the uphill energy will transfer to motion energy just before the brick hits the ground."* (Lewis and Foxcroft, 1991, p123)

And the authors of another of these textbooks 'justify' it as follows:

> *"The key point is that energy is* **transferred** *for jobs to be done. The older ideas that energy is 'changed' from one 'form' to another are now out of favour (...).*
>
> *Nevertheless, if you feel it would be helpful to your pupils, a photocopiable Extension Sheet on 'Types' of energy is included in the* Teacher's Guide *and could be used this lesson or next."* (Johnson et al, 1995, p77)

### *Curriculum development projects and commercial textbooks*

Some of the textbooks were written as part of a curriculum development project and others were straightforward commercial textbooks. In the sample, the latter were in the majority (19 out of 24).

Three of the five curriculum development project textbooks use the ‘energy transfer’ approach. The other two (all pre-NC) belong in the category of the ‘transform ‘plus’’ textbooks, that is they talk mainly of ‘energy transformations’ with only few references to ‘energy transfers’ added on. Interestingly, none of them subscribes solely to the ‘energy transformation’ approach.

There are six textbooks which adopt the ‘energy transfer’ approach. The first solely ‘energy transfer’ textbook ‘Patterns’ (Bausor et al, 1974) was written as part of the Schools Council Integrated Science Project (SCISP) as far back as 1974. SCISP was an innovatory project in many ways, and was very much the precursor and instigating force behind the National Curriculum change concerning the teaching of energy. The influence of this project may also be evidenced by the fact that its approach to the teaching of energy was very quickly (the same year) imitated by a commercial physics textbook, which, in addition, bears the similar title ‘Patterns in Physics’ (Bolton, 1974). The two other commercial ‘energy transfer’ textbooks, one of which is for the study of physics at an advanced level, made their appearance only after 1993.

Overall from the 15 commercial textbooks, which were published after the introduction of the innovation, only two adopted it. Five remained faithful to the ‘energy transformation’ idea; four seemed to add few elements of the new approach either in an ad-hoc way or in very specialised contexts; and four moved to a mere verbal change - although they substituted ‘transfer’ for ‘transform’, they used ‘transfer’ exactly as they had used ‘transform’ before, that is they changed the lexicon but not the semantics.

### *References*


Bausor, J., Hall, W., & Mowl, B. (1974). Introduction: learning about energy. In *Patterns: Teachers' guide 3* . Schools Council Integrated Project (SCISP). London: Longman Group Limited.

Bolton, W. (1974). 3. Energy. In *Patterns in Physics*. McGraw-Hill Book Company (UK) Ltd.

Garrick, T. (1991). Energy. In *Simon & Schuster Modular Science. Teachers' Handbook: Key Stage 3* . Simon & Schuster Education.

NUFFIELD (1966, 1977). Section VI: The teaching of energy in this programme. In Eric M. Rogers & E. J. Wenham (Eds.) *Revised NUFFIELD PHYSICS - General Introduction*. London: Longman Group Limited.

NUFFIELD (1993). *Nuffield Science for Key Stage 3. Science Year 8 Teacher’s guide.* Harlow: Longman Group UK Ltd.

Lewis, J. L., & Foxcroft, G. E. (1991). 11. Energy. In J. L. Lewis (Eds.) *Longman Science 11-14. Physics*. Longman Group UK Ltd.

Johnson, K., Adamson, S., & Williams, G. (1995). *Spotlight Science Teacher’s Guide 7*. Stanley Thornes (Publishers) Ltd.

Porter, A., Wood, M., & Wood, T. (1991). 5. Energy. In *Science Companions*. Stanley Thornes (Publishers) Ltd.

***Briefing Sheet 10***

# ‘Energy transfer’: case study commentary

*Activity H1 is concerned with case studies looking at the use of ‘energy transfer’ ideas in lessons about energy. Activity Resource 1 gives some information about the lessons of two student teachers, and in the STTIS report there is some more detail about these two case studies. There is also information in the STTIS report about further case studies and interviews, and a discussion of the findings. These points are summarised here.*

The findings seem to indicate that the intentions of the innovators of the National Curriculum may not be fulfilled in today’s teaching of energy. None of the case study teachers shows any evidence that they have seriously thought about the difference between ‘energy transfer’ and ‘energy transformation’. For at least one teacher, the difference was perceived to be *“just in the language”*. The notion of ‘energy transformation’ is retained, and although the term ‘energy transfer’ has been partly adopted in the teaching of energy, its conceptual implications have not. In other words whereas most teachers do not explicitly the term ‘energy transformation’, they see no problems in talking about energy being *transferred* from one *form* to *another*. This linguistic amalgamation of fundamentally different concepts and ideas is often one of the unfortunate results of a curriculum change. Often the teachers adopt the suggested new ways of talking about something, but not the meanings these new terms are meant to convey.

Though one teacher found ‘energy transfer’ an easier word, to be used with younger pupils, most suggested it should be used with older pupils and did not restrict themselves to a strict use of it in their teaching. The reasons given were:

- ‘energy transfer’ is more scientifically correct, but more difficult;
- ‘energy transfer’ is a more abstract, complex and less accurate model;
- ‘energy transfer’ comes after the teaching of waves and particles.

The teachers also raised issues of uniformity, consistency and authority in order to explain why the ‘energy transfer’ concept and not the ‘energy transformation/change’ one appears in the National Curriculum document for science.

A certain kind of specialisation of the ‘energy transfer’ concept to particular kinds of processes became obvious both in the suggestions the (student) teachers made about its use and in the examples they used. ‘Energy transfer’ was seen as more pertinent for microscopic accounts of changes and for processes which involve heat transfer. Thus the teachers found it easier to talking about the processes of convection, conduction, evaporation and radiation to older pupils using the idea of ‘energy transfer’, whereas, with no exception, they found impossible doing the same in the context of energy efficiency and with younger pupils.

In summary, the teachers in theses case studies accommodated the new nomenclature to their existing schemas. Their underlying conceptions did not alter, only the terms they used to express them. A similar finding also emerged in the analysis of the science textbooks, as has already been discussed in Briefing Sheet 9. Almost a quarter of the post-NC textbooks makes use of the ‘energy transfer’ idea to convey little more than the idea of ‘energy transformation’.

This accommodation of the ‘new’ in the ‘old’ in the textbooks and in the teacher case was sometimes made explicit. Some of the textbooks seemed to acknowledge the issue and attempted to take a position in relation to it. Also the student teachers identified differences between the two ways of talking about energy and gave reasons for using one in preference to the other.

***Briefing Sheet 11***

# 'Energy and Change': case-study commentary

*Activity H2 is concerned with a case study looking at the use of 'Energy and Change' ideas in lessons about energy. Activity Resource 2 gives some information about examples of the use of the ideas in schemes of work and lessons, and in the STTIS report, there is some more detail about this case study. There is information in the STTIS report about further case studies and interviews, and a discussion of the findings. These points are summarised here.*

This case-study is about an experienced teacher, Ivan, who is attempting to integrate the 'Energy and Change' materials into the existing work of the department. We might characterise Ivan's approach to the materials as 'welding the new to the old'. He attempts a difficult task in adding a novel approach to what already exists without making any waves.  He is not going for the 'whole or nothing' approach, nor for the 'perfect or nothing' approaches. Piece by piece, trial and error are the ways he sees curriculum reform as happening.

The 'Energy and Change' approach appeals greatly to Ivan.  He sees that a science teacher's job is to widen the pupils' perspective so that they can actually think in the abstract, which is according to him what science is all about. He has a great faith in the new approach and embraces some of its fundamental characteristics.  However his use of it and his incorporation of it in the existing schemes of work reveal also that he has not espoused other equally fundamental characteristics.

Thus, Ivan does not seem to see any contradiction between the 'energy transformation' approach and the 'energy transfer' one, the latter being inherent to the 'Energy and Change' innovation. We could say that he has *accommodated the new in the old.* He has recruited the project pictures for the purpose of putting some 'mechanism' to the abstract boxes (showing one form of energy changing into another) that he already used.

There is no evidence that Ivan has embraced the principal premise of the innovation, which is that differences (of concentration, temperature, etc.) drive change. He calls them 'energy difference diagrams' which rather suggests the contrary, since according to the new approach a flow of energy is not caused by an *energy difference*, but by, for example, an *energy concentration difference*.

Ivan seems to appreciate the opportunity that the abstract pictures give him to tackle the issue of reversibility. He does not, however, perceive changes which 'just happen' as driving those that do not, at least in the way it was intended by the innovation.  He talks of a downhill change as a process that delivers the energy needed for an uphill change to happen.  "*You need to pump energy in to make it happen*", he told his pupils referring to a non-spontaneous change.

Another choice Ivan seems to have made is not to use the more generic and abstract picture of a 'spring' relaxing to talk both about a mechanical spring and a 'gravitational spring' relaxing. Instead he uses a more concrete picture (showing a ball 'Before' at a distance from the Earth, and 'After' on the Earth) to depict falling, and he keeps the one with the spring to talk about the change of a mechanical spring.  This might have been a deliberate decision of his to use on the whole pictures that are not very abstract. The use of the same picture to represent both mechanical springs and 'gravitational springs' is an important step in the development of the idea of a 'chemical spring'.

Before looking at some general conclusions about the research into teachers' transformations of the 'Energy and Change' materials, it is useful to consider briefly the other case study that is discussed at length in the STTIS report. Here, the approach was to create a new topic called 'Energy and Change' into the Y7 curriculum which consisted exclusively of the innovations teaching materials. The idea seemed to be that the pupils would learn about the basic new ideas, terms and abstract pictures in one large dose, so that teachers in subsequent topics could draw on this knowledge. In the lesson observed, the teacher understood the activities clearly and what they tried to achieve, and faithfully followed the teaching suggestions that accompanied them.

Isolating and insulating the novel approach from interaction with other teaching material makes its teaching possibly easier, but robs the children from the opportunity of seeing it working in the context of or alongside more familiar activities. Thus, the major transformation here was one of sequence and integration of the innovation rather than of content. The innovation was adapted to an educational philosophy that was not imagined by its creators. It was intended to interact with other teaching materials so that the effected change would happen incrementally; it was transformed into a scheme in which a large dose of vocabulary was to be learned in isolation.

In these two case studies, the ‘Energy and Change’ innovation was transformed and adapted in each case to the school’s ethos, to the teachers’ pattern of work and to what the teachers already knew. The innovation is not prescriptive but provides teachers with curriculum materials and a general framework for their use, which means that it is open to a number of different kinds of transformation. Transformations may arise from the adoption of an innovation at the microscopic scale, which is the context of the teacher’s classroom, but also those arising at the macroscopic scale, which is the context of a whole school.

In the first case we have integration at the macro level which is more in line with the intentions of the designers of the innovation. We have however very important transformations at the micro level, since the adoption of the innovation did not go as far as adopting fully its ways of thinking and talking about energy. In the second case we have a huge transformation at the macro level - in how the work is organised. However, in those instances where the teacher fully understands the ideas behind the innovation, as happened in our case, we see almost no transformations at the micro level - the level of the teaching in the classroom.

***Briefing Sheet 12***

# Dimensions of analysis

Activity Resource 3 gives a summary of the analysis of the STTIS research about the factors that affect transformations of curriculum innovation. In the analysis, three broad dimensions are discussed.

- The relationship to accepted subject content
- Teachers' convictions (beliefs about learning, and values)
- Teachers' habitual practices, and those expected of them (contexts, customs and constraints)

This sheet reproduces the material in Activity Resource 3, giving examples (in boxes) of these factors related to the 'Energy transfer' and 'Energy and Change' case studies.

## The relationship to accepted subject content

An important issue is teachers' concern for the match of an innovation to existing syllabus content. This is especially true in the cases where the 'up-take' of an innovation is optional. The innovation is easier to accept when the content-distance between the 'new' and 'old' knowledge is rather small. Moreover, innovations are easier to accept if they address:

- Curriculum areas not presently taught but which teachers would value. (Note that in many systems this would involve the development of new curricula so that work on these new areas would not be seen as distracting from the syllabus content).
- Those curriculum areas currently taught but where teachers believe that present methods are ineffective. Experimentation is more likely to be viewed as reasonable if what exists is felt not to be good.

How may the 'new' be seen in relation to the 'old'. The following two kinds of transformation were observed in the research:

**'New' is considered as an add-on to the 'old'.** The innovation is 'added to' rather than 'substituted for' something else. In this case, certain ideas of the innovation are included, but the adoption of the general framework of the innovation is ignored or deferred and thus possible contradictions between the new and the old are ignored. There is a good deal of switching between using the innovation and not using it depending on the context. 'Old' and familiar contexts attract 'old' and familiar strategies.

| |
|---|
| 'Energy transfer' innovation: All the teachers in the case studies suggested some kind of use for both the 'energy transfer' and 'energy transformation' concepts. They offered invented rationalisations about which is easier and which is harder and suggested some kind of specialisation for the use of each concept according to different subject contents or age and ability of users. In other cases this specialisation was triggered by the context itself. So, a circus of contraptions around the lab, for example, called 'energy circus', set up for pupils to interact and discuss using the language of 'energy', seemed to induce more readily talk about 'energy transformations' than about 'energy transfers' to teachers and then subsequently to pupils. |

‘Energy and Change’ innovation: Ivan’s case is a variation of this transformation, because he did not simply add few new ideas to the existing ones, but he systematised their use by making them an essential component of an overarching approach to the teaching of energy. He however also deferred adoption of the general framework of the innovation and ignored the contradictions between the new and existing ideas. For Ivan the context and the other people to be affected by the implementation of the innovation became prominent at the expense of the innovation itself. The innovation became something to be negotiated rather than to be adopted as it is, and the nature of the innovation was completely altered as a result of these negotiations.

**The ‘new’ becomes like the ‘old’.** Teachers transform the use of an innovation to one as close as possible to a more traditional structure of content. The existing framework remains unchanged, and the new ideas are adapted so that they may be accommodated within it.

‘Energy transfer’ innovation: In most of the cases the innovation was adopted only at the verbal level and it consisted of substituting the new phrase for the old phrase, i.e. of using ‘transfer’ to mean ‘transform’ in contradictory phrases such as ‘energy is transferred from one form to the other’, but not really changing anything else. In other words, the (student) teachers accommodated the new nomenclature to their existing schemas; their underlying conceptions did not alter, only the terms they used to express them. A similar finding also emerged in the analysis of the science textbooks.

The teacher’s perception of the degree to which an innovation ‘fits’ the required subject content is critical to its acceptance. If the fit is not good enough, the use of the innovation will be transformed to make the fit closer. Where the innovation carries with it both a new ‘tool’ *and* new subject matter, and the latter is too far from what a teacher expects or understands, both are likely to be transformed. But against this, there are some successful ‘curriculum packages’ which put together new tools, contents and practices in a convincing way.

## Teachers’ convictions (beliefs about learning, and values)

It is striking that, when asked, most of the teachers in the case studies express strong convictions and beliefs about what should be taught in the classroom, and about what can facilitate learning and engage students. It seems that teachers develop strong views, on which they act, and any proposal which runs counter to those views is unlikely to succeed. In consequence any proposal for the use of an innovation is likely to meet objections on the grounds of some conviction, which will have to be overcome if the proposal is to succeed. Some characteristic kinds of conviction are:

**Convictions about goals for students:** Teachers, as one would expect, have strong views about what ideas can be taught with a particular age of pupils. It was not the case that all teachers agreed about what would be easier or more appropriate with a particular age of pupils; nevertheless, they seemed to repeatedly appeal to this notion of easiness or appropriateness for their students, when they talked about using a particular approach.

Most of the justifications the teachers gave for why they used or not used a particular way to talk about energy had to do with whether they thought it would be understood by, or it would be appropriate to the age of pupils they had. The notion of what pupils will find easy or difficult proved especially important in whether teachers considered adopting the novel approach developed by the ‘Energy and Change’ project. In this case, what was particularly interesting was that teachers’ concerns about what the pupils might find difficult to understand and complicated to use were not confirmed by our trials of the materials in the classrooms. Moreover, all teachers who participated in the trials did not hide their surprise with the ease with which the pupils used the new materials.

**Convictions about time:** The notion of time, whether this was preparation time for the teachers, preparation time for the pupils, or teaching time that an innovation would require, was an important consideration for the teachers. This played an important role when the implementation of an innovation was considered optional by the teachers.

## Teachers' habitual practices, and those expected of them (contexts, customs and constraints)

Every case study shows a teacher trying to achieve a fit between the use of the innovation, and the habitual classroom practices with which that teacher and his or her class are familiar.

**Old resources and practices:** Where the innovation itself was not accompanied by detailed guidelines or teaching material to use, the intentions of the innovation were liable not to survive into the actual teaching event when they were in conflict with or marginal to the teacher's practices.

> The 'energy transfer' National Curriculum innovation was not accompanied by guidelines about its implementation. The student teachers despite endeavouring more to comply with the NC recommendations and thus making some move towards using the concept of 'energy transfer', fell back on the customary practice of describing energy exchanges in terms of transformation when they used the school's teaching resources with their pupils.

**Integration of the innovation into the teaching process:** The extent to which an innovation is integrated with other teaching materials varies widely. Innovation may be isolated from the curriculum, and may happen as single' one-off' lessons. On the other hand, innovations may be integrated cautiously, through small-scale integration of new ideas into old materials.

> There were two kinds of integration of the 'Energy and Change' innovation in the teaching process. In one, the novel approach was isolated and insulated from interaction with other teaching material. The innovation was transformed into an 'intensive language course' that would give the pupils the vocabulary to use and build on later on. In the other, the novel approach was incorporated cautiously, by piece-by-piece welding of the new material to the old.

**Examinations and syllabus requirements:** It seems to be of paramount importance that teachers perceive the innovation as addressing or helping towards fulfilling the examination syllabus requirements.

> For many teachers the failure for the successful uptake of the 'energy transfer' innovation is attributed to the fact that this innovation is not reflected in the examination syllabus requirements – many examination papers apparently still require pupils to identify energy forms and changes. Also, in the case of the 'Energy and Change' innovation, the effect of the new approach on pupils' performance in the exams was a constant concern of the teachers who used it.

***Briefing Sheet 13***

# Teachers' reactions to ‘Energy and Change’ materials

This sheet gives some impression of teachers' reactions to the ‘Energy and Change’ materials. Two sources have been used. A group of teachers in one school, who had used the materials, were interviewed afterwards to see what they felt about the experience. The same questions were also put, but in questionnaire form, to 42 teachers who had attended one-day INSET sessions about the materials, to test immediate reactions.

## *Thinking about the scientific ideas*

One obvious issue is whether teachers saw the materials as raising fundamental scientific issues of importance and leading them to re-think some of their own ideas. All the teachers who attended the INSET days agreed that the ideas are fundamental and can help link together many parts of science, up to GCSE and beyond. All but a very few agreed that the work gets teachers thinking again about ideas they may not have been too sure of, and helps them sort out these ideas a bit better, though on another question one third doubted whether there were really new ideas.

Amongst the teachers interviewed, the head of science, agreeing that the ideas are fundamental, said:

> *"They're fundamental because they're probably essential ideas to understand ... that's what I found very satisfying about it ... none of it has been a waste of time ... if they can retain and build on what they've got it could have a very interesting effect if we could follow those groups through to GCSE."*

Another of these teachers looked to basics:

> *" ... the ideas behind what I was teaching were certainly very fundamental ... the children can't progress onto understanding the way matter behaves or about chemical changes unless they understand about mixing and things like that."*

She agreed that the materials had made her think, and that she had seen how they fitted ideas together:

> *"I had to think very hard on a couple of things ... it's good. Also I found it makes me really understand the ideas behind a lot of the things you're meant to be teaching them anyway ... You tend to do lots of things in isolation - in bits and pieces - for example the energy topic. You don't really see a progression or a theme and you definitely do when you're using these materials."*

The head of science saw potential benefit for staff as a whole, and for herself:

> *"As far as helping staff understand what they're trying to teach, it's a fresh way, you know, and if you're not sure of an idea it gives you a chance to check it with somebody else. I found it very interesting, particularly the idea of one change driving another ... sorting out ideas for myself ... I've found it at times very challenging, but enjoyable and quite rewarding."*

About whether there are really new ideas here, one teacher perceptively remarked:

> *"It brings to the fore ideas which are usually too buried, like the idea of always looking at the change."*

### *Children's understanding of the ideas*

If the work challenges teachers, can pupils cope with it? Almost all the INSET teachers thought that the materials would keep children active and busy, discussing and thinking, but two thirds were worried that the pictures would prove too abstract and have too many hard-to-remember conventions. Three quarters saw the work as an accessible way of introducing the particle nature of matter for Years 8 and 9. But they were about equally divided on whether there is too much special and non-scientific vocabulary and on whether the materials could work with low ability pupils and ones with language difficulties. Nearly all thought that the materials could help teachers find simple ways of talking with pupils about energy and physical and chemical changes. And nearly all thought that the activities offer a challenge to higher ability pupils to think hard.

The teachers interviewed were from an inner city comprehensive with at least its fair share of children of modest ability, and whose pupils had thirty or more first languages between them. These teachers tended to be particularly positive about the use of pictures and simple non-technical language:

> *"If you teach them what the diagrams mean ... then I didn't have any problems at all. Most of the children were understanding what they were meant to be seeing. I find it easier using the diagrams for our students that have lower English abilities ... that makes the work accessible to them."*

> *"I think if anything using simple words like spreading out and bunching together has made the children understand it straight away, and once they've got that understanding then you can use the proper words."*

> *"I've been very surprised at the number of times some of the less able children have come up with the right answer ... I'm convinced they are able to follow those pictures and apply them to new situations."*

They broadly agreed about the value of the discussions amongst pupils:

> *"It gets the kids talking to one another, so as a tool ... to introduce them to talking science it's good ... there's very few good materials to do that."*

Of course there were doubts mixed with positive reactions:

> *" ... the children can't find a book where they use words like concentrating and spreading out ... if the children want to go home and learn it won't make any sense."*

> *"One can spend a lot of time teaching the pictures. But the pupils whose language is poor or who are bilingual probably in the end get a better understanding than they would ... without the pictures. The benefits outweigh the problems."*

Broadly the teachers who used the materials saw it as working for most pupils and as challenging for many:

> *"It's working really well and the pupils really seem to have a better understanding - they could apply it to the extension work they are now doing".*

> *"Every single kid in the class, no matter what their ability, can get something out of it, and they do have to think about it before they can do it ... They are busy all the time. And positively on task."*

> *"I think some of it challenged (one of my best pupils). It was good for him - he would have to think about it. When he was writing his own examples he'd have to sit and think about that."*

> *"They were quite proud of themselves at actually having to understand something quite difficult - they liked that."*

One teacher was a bit cynical about whether understanding was what was going to be tested:

> *"Everything now is seen as a vehicle for achieving better examination results. Nobody is interested any more in pupils understanding what's going on. And I don't doubt that this work helps kids understand things better, but whether it helps them understand examination questions better (I don't know)."*

### *Relating to practical experiences*

In the activities, pupil discussion obviously has to be based on a lot of first hand experience, whether in everyday life or in the laboratory. Because we have concentrated on developing pencil-and-paper activities, it would be easy - but wrong - to suppose that we do not care about associated practical experience. What is needed is however already either being done or is rather obvious, so we kept our attention on what to do with that experience. The teachers doing the INSET seemed largely to take this point: two thirds denied that practical experiences might be better than all the work comparing pictures, and all but one or two agreed that it is easy to see how the activities could build on practical work. And nearly three quarters denied that the ideas are too general, better replaced by particular things to think about. The teachers who used the materials were clear about the need for a mixture:

> *"We did practical work before we went onto those things - (you need) a sort of a mixture really."*

> *"Instead of giving pictures of what's happening it could be done in front of the class."*

> *"I think some practical experiences are very confusing - there is no point in doing a practical if there's not been a lot of talk about it beforehand."*

### *Incorporating the materials into the curriculum*

The materials are not a complete course, but are intended to be incorporated flexibly in existing schemes of work. Is this possible? Eighty percent of the teachers doing the INSET thought it would be possible to find places for the activities in their schemes of work, and more than three quarters agreed that they could easily be used alongside existing schemes. Amongst the teachers interviewed, the head of science saw some virtues related to the style of work and problems arising from the skills required of pupils and the effort required of teachers:

> *"I can see how I can find good places to fit the activities in because there's a lot of talking and discussing - you can often be glad of that emphasis. The Year 7 stuff, that is definitely going into schemes of work."*

> *"At the moment I believe it will be an extra to the scheme, but I think staff will dip into it and that's what we're going to encourage them to do rather than to say that this has got to be used."*

She was realistically clear that some of the work would take time to get absorbed into staff thinking:

> *"The energy stuff, though I think it can be well integrated, I have a feeling that (the idea of) one change driving another will not be taught by many of us ... it would need an INSET on what it means. You're asking them to learn something else ... and since they've done it successfully in their opinion another way they might just stick to their other way."*

***Briefing Sheet 14***

# Summary of research on teachers' transformations

These workshop materials have focused on two curriculum innovations and their uses by the teachers. This sheet summarises some general conclusions about the transformations made by teachers. More detail is included in the STTIS report.

Transformations came in two broad types. There are those which occur when the innovation is imposed and the people who are called upon to implement it are *not* committed to it and do *not* understand it; and those which occur when the people who are called upon to implement it *are* committed to it and/or *do* understand it.

The first type often includes transformations that happen simply at the verbal level, substituting the new phrase for the old phrase, but not really changing anything else. There is also a good deal of switching between using the innovation and not using it depending on the context. In other words there is an apparent specialisation of the innovation according to different contexts or users. 'Old' and familiar contexts attract 'old' and familiar strategies. A variety of contraptions around the lab, for example, (an 'energy circus'), induces more readily talk by teachers about 'energy transformations' than about 'energy transfers'. In general, we usually have transformations of the 'new' so that it becomes like the 'old'. We also have some transformations of the 'old' to fit the 'new', but these are clumsier and seem to result in a struggle. All the above behaviours were detected in the writing of textbook authors as well as in the practice of teachers. When innovations are imposed from the top, teachers will obey authority if necessary and accept to adopt the innovation, but they can subvert it in the classroom if they do not understand it or see the effectiveness of it.

In the second type of transformations, which are the ones brought about by people who understand the innovation, the context and the other people to be affected become prominent. Then the possibility of action becomes an issue and the innovation becomes something to be negotiated rather than to be adopted as it is. Consequently, the transformations vary a lot, depending on the relationships between the people involved, especially the existing power relationships between them. Hence we see different strategies being followed in the implementation of the innovation, strategies which are explicable in terms of the people involved rather than of the nature of the innovation itself.

A key factor is the extent to which an innovation does something which is related to what the teacher has customarily been doing, as least in the mind of the teacher. Adjustment is perceived necessary until it is sensed that it fits. In doing this adjustment teachers will apply lots of criteria which often have nothing to do with the nature of the innovation and its merits. These criteria are usually work-related and reflect practical concerns about whether for example a particular activity will stretch pupils enough or too much, or whether it will keep the pupils occupied and interested, or even whether it requires extra preparation work and time from the part of the teachers. These considerations are very prominent for teachers, even if they are not always for curriculum innovators.

It is useful to make a distinction between the levels at which the transformations happen. The macroscopic level is the level of the whole school or department that adopted the curriculum innovation, and the microscopic level was the level of the teacher and his/her classroom. It is possible for the transformations at one scale to reflect the transformations at the other, but it is not necessary that they do.

Finally, for both innovations, it was true that mere acceptance of their merits was not enough for their successful take up. Deep understanding and commitment to the innovation appeared to be some of the preconditions. In addition, attention to the details as well as to the general framework of the innovation is essential, since it is these details which may often undermine its overall effect.

## Science Teacher Training in an Information Society (STTIS)

## Teacher Workshop (UK)

# Teaching about energy

## Activities for Workshop 1 (Sections A – G)

## Teachers' Workshop 1

### *Introduction*

This first workshop is designed to help you to plan and teach a trial lesson about energy using materials related to the innovations. In a second workshop you will evaluate this trial lesson, drawing on research findings, and plan further work. To support you in planning the trial lesson, in this workshop you will:

- review your current practice on the teaching of energy;
- learn more about the curriculum innovations;
- review some of the research findings through 'stories' about teachers' implementation of the innovation;
- plan a trial lesson that takes account of the aspects above.

For more details about the rationale behind the workshop, look at the section on Aims. If you want to see a list of all the activities in the workshop, go to the Activities section, from where you can also download Word files of the activities.

*Aims*

The main aims of the activities are:

Section A: Exploring current practice

- To review how energy is currently taught throughout your existing science curriculum.
- To evaluate your existing teaching about energy.
- To identify particular areas of existing teaching that you would like to address.

Section B: Learning about the innovation

- To apply the ideas of 'energy transformation' and 'energy transfer' approaches and consider the merits and difficulties of each
- To clarify some important scientific ideas related to energy.
- To learn about key ideas of the 'Energy and Change' materials.
- To carry out some of the 'Energy and Change' activities using abstract pictures.
- To consider examples of the work of pupils doing these activities.

Sections C, D, E and F: Transformations of curriculum innovations

- To compare different ways in which teachers may transform the 'Energy transfer' and 'Energy and Change' innovations.
- To explore factors that may influence the transformations.
- To consider these issues in the light of your own teaching experience.

Section G: Planning

- To plan, teach and evaluate a lesson drawing on the new ideas introduced in these workshop materials.
- To prepare for the next workshop session by reading case-study material.

*Activities*

This is a list of all the activities in the first workshop. If you want to browse through the activities, then you can view these documents directly as web pages. If you wish to do the activities, in most cases you will find it easier to download the documents as Word files.

Section A  Exploring current practice
- Activity A1: Auditing current practice
- Activity A2: Evaluating current practice

Section B  Learning about the innovation
- Activity B1  Forms of energy
- Activity B2  Energy transfers
- Activity B3  Forms of energy and energy transfers compared
- Activity B4  Energy from hot to cold
- Activity B5  Insulation
- Activity B6  Things that 'just happen' and things that don't
- Activity B7  Storing energy
- Activity B8  Fuels and food

Section C  Transformations: content
- Activity C1: Energy transfer
- Activity C2: Energy and Change

Section D  Transformations: beliefs about learning
- Activity D1: Energy transfer
- Activity D2: Energy and Change

Section E  Transformations: values
- Activity E1: Energy transfer
- Activity E2: Energy and Change

Section F  Transformations: contexts, customs and constraints
- Activity F1: Energy transfer
- Activity F2: Energy and Change

Section G: Planning
- Activity G1: Using the new ideas

## *Section A  Exploring current practice*

In this section, you will review and evaluate how energy is currently taught throughout your existing science curriculum, and identify particular areas that you would like to address. In considering how you might introduce new ideas into the curriculum, it is clearly important to consider what is already there.

It may be possible simply to add a new approach to existing approaches, though it may be, for example, that an existing approach needs to be modified to allow a new approach to be incorporated. Understanding the nature of existing approaches will help to put into perspective the new ideas about energy that will be introduced in later activities. The new approaches may or may not address the problems that you identify, but by defining your own agenda, it will help to put the new ideas in perspective.

The activities in this section are:

- Activity A1: Auditing current practice
- Activity A2: Evaluating current practice

## *Section B  Learning about the innovation*

The activities in this section are intended to help you learn more about the two innovations studied in the research:

- 'Energy transfers' in the National Curriculum;
- 'Energy and Change' project.

*'Energy transfers' in the National Curriculum*  This national-scale innovation was introduced in the first National Curriculum for England and Wales (DES 1989).  The concept of energy transfer appeared to replace that of energy transformation used by previous syllabi and most textbooks for pupils at the secondary level.

*'Energy and Change' project*  A smaller scale innovation introduced by the curriculum materials developed by the 'Energy and Change' project (Boohan and Ogborn 1996).  This project aimed to provide novel ways of teaching about the nature and direction of changes and energy, in particular introducing ideas related to the Second Law of Thermodynamics in a way accessible to pupils aged 11 upwards.  To accomplish this, the project developed an abstract picture language through which the scientific story is told.

- Activity B1  Forms of energy
- Activity B2  Energy transfers
- Activity B3  Forms of energy and energy transfers compared
- Activity B4  Energy from hot to cold
- Activity B5  Insulation
- Activity B6  Things that 'just happen' and things that don't
- Activity B7  Storing energy
- Activity B8  Fuels and food

## *Section C  Transformations: content*

This is the first of four sections which looks at the transformations made by teachers of curriculum innovations, and the factors affecting these. This section looks at transformations in the subject content, through the use of stories based on research into the work of teachers implementing this innovation. The activities look at the views that teachers have about the scientific ideas in the 'energy transformation' and 'energy transfer' approaches, and at the approach of the 'Energy and Change' materials. How do these approach relate to what is currently taught, and how can the ideas be incorporated into existing schemes of work?

The activities in this section are:

- Activity C1: Energy transfer
- Activity C2: Energy and Change

## *Section D  Transformations: beliefs about learning*

This section continues with the use of 'stories' about teachers' transformations based on research. The focus here is on exploring factors related to teachers' beliefs about learning. When teachers were asked how they approached teaching about energy, and their reasons for it, they had strong views about how pupils could be supported in their learning. . What kinds of approaches to energy do teachers think that pupils will find easier? Which gives them a better understanding of the science? Does it depend on their age or what they are studying?

The activities in this section are:

- Activity D1: Energy transfer
- Activity D2: Energy and Change

## *Section E  Transformations: values*

Our actions are guided by what we see as important and what we value. This section looks at the factors related to personal values that may influence teachers' transformations of the innovations. Again, the issues are addressed through the use of 'stories' based on results of the research. When teachers described their work on teaching energy, they referred to personal values about what should be in the curriculum and how it should be taught in the classroom. What kind of science should pupils be taught? What is the nature of scientific knowledge? What kind of science is defined by the National Curriculum? How important is it that pupils should be able to abstract fundamental similarities and differences between changes? Is it necessary to include 'Second Law' ideas in the curriculum? What purpose do they serve?

The activities in this section are:

- Activity E1: Energy transfer
- Activity E2: Energy and Change

## *Section F  Transformations: contexts, customs and constraints*

This is the final section which looks at the transformations made by teachers and the factors affecting these. The activities in this section focus on the way in which innovations are constrained by the contexts within which teachers work and their customary practices.

Even when teachers were committed to the innovation, it might not always have been easy to implement it because of the particular contexts within which they worked. How are teachers affected by factors related to science department of the school? How are they affected by factors outside the school, including the national context? What are the constraints of the individuals themselves? Will learning about these novel ideas be of benefit to pupils? How will it affect teachers' motivation and commitment?

The activities in this section are:

- Activity F1: Energy transfer
- Activity F2: Energy and Change

## *Section G: Planning*

In this section, you will use some of the ideas that you have learned in the earlier activities to plan, teach and evaluate a lesson. In planning and evaluating your lesson, you will be thinking about the 'stories of transformations' and how these relate to your own practice. In this way, you can consider how your choices have been influenced by factors such as subject content, your beliefs about learning, your values, and by customary practices and constraints.

In the next workshop, you will be discussing the planning and evaluation of this lesson, and drawing on this experience for a more detailed study of the case studies and findings of the research work.

The activity in this section is:

- Activity G1: Using the new ideas

## Activity A1 Auditing current practice

### *Aims*

- To review how energy is currently taught throughout your existing science curriculum.

### *Background*

In considering how you might introduce new ideas into the curriculum, it is clearly important to consider what is already there. It may be possible simply to add a new approach to existing approaches, though it may be, for example, that an existing approach needs to be modified to allow a new approach to be incorporated. Understanding the nature of existing approaches will help to put into perspective the new ideas about energy that will be introduced in later activities. In this activity you will review how the concept of energy is dealt with in your existing schemes of work and in the textbooks that you use, and identify some of the general features of the approaches used.

### *What to do*

1. Look at your schemes of work. Which units include important ideas about the energy concept? What are the key ideas about energy to be learned in each of these units? How do the units relate to each other, and how is the energy concept developed?

2. Do you use more than one textbook? If so, are there differences in the ways that they deal with the energy concept?

3. Look at the tests on units that include ideas about energy. What kinds of knowledge about the energy concept are pupils expected to learn? Which aspect is most emphasised?

4. How could you summarise in a few sentences, the approach to energy in your existing teaching? The following questions may provide a focus for your thinking:

- Is energy defined clearly from the start, or is it a concept that gradually acquires meaning as pupils use it?
- Is energy considered as something which pupils can experience directly in practical activity or is it a more theoretical idea?
- Is energy seen as a unifying concept throughout the science curriculum, or is it dealt with differently in, for example, biology chemistry and physics?

## Activity A2 Evaluating current practice

### *Aims*

- To evaluate your existing teaching about energy.
- To identify particular areas of existing teaching that you would like to address.

### *Background*

You may have already identified aspects of teaching about energy that you think are problematic, and that you would like to try to address. This activity may help to clarify these and to identify others. Before looking at new ideas about the teaching of energy it is helpful to look at problems with existing approaches. The new approaches may or may not address the problems that you identify, but by defining your own agenda, it will help to put the new ideas in perspective.

### *What to do*

1. Working as a group, identify those aspects of your existing teaching of energy which work well.

2. Now try to identify as many problems as you can in the teaching of energy. These may relate to a number of factors, for example:

- pupils' difficulties in the understanding of the concept
- inconsistencies in the approaches used in different textbooks or within the same textbook
- problems with the way that the science is dealt with at school level
- your own difficulties in understanding the science or in explaining the science in a way appropriate to pupils

3. From your group's list, choose one or two that you as an individual consider to be the key difficulties.

**Section B Learning about the innovation** **Page 1 of 2**

## Activity B1 Forms of energy

### *Aims*

- To apply the idea of ‘forms of energy’ and ‘energy transformation’ to a variety of phenomena
- To consider some of the difficulties raised by this approach to teaching about energy

### *Background*

A very common way in which energy is dealt with in school textbooks is the ‘forms of energy’ approach. Energy is introduced as existing in different forms (e.g. heat energy, electrical energy, sound energy). Energy may be converted from one form to another during the course of a change. In some approaches it is suggested that it is the conversion of one form of energy to another is the cause for the change to happen. A popular way of introducing this idea of energy ‘transformation’ is through the use of an ‘energy circus’, in which pupils identify the energy changes taking place in a variety of different phenomena. Though this approach is popular, the National Curriculum has never referred to ‘forms of energy’ in any of its various versions since it was first introduced. Many people have argued that the forms of energy approach raises a number of difficulties.

In this activity you will first look at a energy circus as if you were a pupil doing the activity, writing down the energy changes taking place. You will then begin to consider some of the difficulties with the approach.

### *What to do*

1. The table on page 2 shows some apparatus commonly used in an ‘energy circus’. Look at the questions on this sheet and write the answers on the table.

2. How many different ‘forms of energy’ did you identify? Is this a ‘complete set’ of different forms of energy, or are there others that are not included? Did different people in the group agree about the forms identified?

3. Some people might say that ‘chemical energy’ is too abstract, and that it is better to associate forms of energy more directly with the things that contain the energy. Do you think that it helps to have terms such as ‘food energy’ and ‘fuel energy’. What about ‘bread energy’ and ‘cheese energy’? Does the term ‘muscle energy’ help to explain what happens during physical activity.

4. Some books illustrate ‘forms of energy’ with objects. For example, chemical energy might be illustrated by a can of petrol, and electrical energy by a torch battery. Is this helpful?

5. A lamp uses electricity and it produces light. How does it add to our understanding to say, for example, that it converts electrical energy into light energy? Or is the word ‘energy’ just a ‘verbal ornament’?

## Activity B1 Forms of energy (cont.)

### *An energy circus: forms of energy*

In the table below are some examples of apparatus commonly used in ‘energy circuses’. For each one, answer to the following questions:

- What forms of energy are involved?
- What energy transformations take place?
- Write down an energy chain to represent what is happening.

The first example in the table has already been done.

| **Example** | **Energy change** |
|---|---|
| 1 A battery in a circuit with a bulb | Chemical energy -> electrical energy -> light energy ( + heat energy) |
| 2 Winding up a clockwork toy car then letting it go | |
| 3 Using a steam engine to drive a dynamo and light up a lamp | |
| 4 A plant growing | |
| 5 Turning a hand-driven dynamo to make a lamp light | |
| 6 A ball rolling down a ramp | |
| 7 Using an electric kettle to boil some water | |
| 8 An electric motor lifting a load off the floor | |
| 9 An electric bell | |
| 10 A hot cup of water cooling down | |
| 11 An electric motor turning a flywheel, then using the moving flywheel to drive a dynamo and light a lamp | |
| 12 Speaking into a microphone connected to an amplifier and a loudspeaker | |

## Activity B2 Energy transfers

### *Aims*

- To apply the idea of 'energy transfer' to a variety of phenomena.
- To consider some of the difficulties raised by this approach to teaching about energy.

### *Background*

Much debate has taken place about ways of teaching about energy, and many people have argued that teaching about 'energy transfer' rather than 'forms of energy' is more useful and scientifically appropriate. Although the 'forms of energy' approach to teaching about energy is popular, the National Curriculum has never referred to it in any of its various versions since it was first introduced, though it does refer explicitly to the idea of energy transfer. Thus, the 2000 version states, for example, that in KS3, pupils should be taught:

- 5d the distinction between temperature and heat, and that differences in temperature can lead to transfer of energy
- 5e ways in which energy can be usefully transferred and stored

At KS4, pupils should be taught, for example:

- 5a how insulation is used to reduce transfer of energy from hotter to colder objects
- 5d to calculate power in terms of the rate of working or of transferring energy

In this approach, then, energy should be thought of as 'staying the same kind of thing' while it travels or is transferred from one place to another. Energy can be stored in objects, for example, an object has more energy stored in it when it is hot than when it is cold, and an object has more energy stored in it when it is moving than when it is still. Springs have more energy in them when they are stretched. Energy can be transferred in a number of ways, for example by a pulley system, by an electrical current, or by radiation.

In this activity you will first look at an energy circus from an 'energy transfer' point of view as if you were a pupil doing the activity, writing how energy is transferred. You will then begin to consider some of the difficulties with the approach.

### *What to do*

1. The table on page 2 shows some apparatus commonly used in an 'energy circus'. Look at the questions on this sheet and write the answers on the table.

2. Which of the changes seemed easy to describe in terms of energy transfer? Which seemed more difficult? Why do you think that some changes seem easier to describe than others?

3. The National Curriculum uses the term 'energy transfer'. So, we could talk of energy being transferred from a hot cup of water to the surrounding air. Which of these others terms could be used appropriately with pupils?

- The energy goes from the water to the air.
- The energy travels from the water to the air.
- The energy flows from the water to the air.
- Some of the energy that is in the water ends up in the air.
- The energy spreads out from the water from the air.

## Activity B2 Energy transfers (cont.)

### *An energy circus: energy transfers*

In the table below are some examples of apparatus commonly used in 'energy circuses'. For each one, answer to the following questions:

- Where is the energy stored at the start?
- How is energy transferred?
- Where is it transferred to?
- Summarise these ideas in the table

The first example in the table has already been done.

| **Example** | **Energy change** |
|---|---|
| 1 A battery in a circuit with a bulb | Energy is stored in the battery. It is transferred by the electrical current to the bulb which gets hot. It then transferred by radiation out into the surroundings. |
| 2 Winding up a clockwork toy car then letting it go | |
| 3 Using a steam engine to drive a dynamo and light up a lamp | |
| 4 A plant growing | |
| 5 Turning a hand-driven dynamo to make a lamp light | |
| 6 A ball rolling down a ramp | |
| 7 Using an electric kettle to boil some water | |
| 8 An electric motor lifting a load off the floor | |
| 9 An electric bell | |
| 10 A hot cup of water cooling down | |
| 11 An electric motor turning a flywheel, then using the moving flywheel to drive a dynamo and light a lamp | |
| 12 Speaking into a microphone connected to an amplifier and a loudspeaker | |

## Activity B3 Comparing approaches

### *Aims*

- To consider the merits of different ways of teaching about energy.
- To clarify some important scientific ideas related to energy.

### *Background*

Activities B1 and B2 looked at two different approaches to the teaching of energy. The first was 'energy transformation' in which energy is seen as something which exists in different forms and which can change from one form to another. The second approach was 'energy transfer' in which energy is seen as staying the 'same kind of thing, but going from place to place. This activity compares these two approaches. It also aims to clarify some of the scientific ideas related to energy, including those of the Second Law of Thermodynamics, which are the concern of the 'Energy and Change' materials discussed in Activities B4 to B8.

### *What to do*

1. Read through the four explanations on page 2. The first two are about water coming out of a bathroom tap, and the second two are about heating some oil with an immersion heater. Each phenomenon is looked at from a 'transfer' perspective and a 'transformation' perspective. Which of these explanations do you think make sense? Which do not make sense? Why?

2. Does it make sense to think of energy as being 'substance-like' and flowing from place to place rather like water does. Or is it conceptually confusing to use a 'flow' analogy? Are there dangers of pupils seeing energy as an actual substance? Do you think that a 'transfer' or a 'transformation' approach to energy is more helpful?

3. Look at the statements on page 3, and for each statement decide whether you think it is true or false. There are some difficult scientific ideas here, which cause most people to think very hard about the answers. This part of the activity is to help you clarify these problematic concepts.

## Activity B3 Comparing approaches (cont.)

1. ‘Transfer of water’

I turn on a tap in my bathroom and put a glass under it. The glass fills with water. The reason is that the tank stores water high up in the roof. Water flows from the tank to the glass, which is lower. So the glass fills up.

2. ‘Forms of water’

I turn on a tap in my bathroom and put a glass under it. The glass fills with water. The reason is that the cold water tank in the roof contains cubic water (the shape of the tank). This is changed into running water in the pipes, and then into cylindrical water in the glass. This can be summarised:

cubic water -> running water -> cylindrical water

3. ‘Forms of energy’

I connect up a battery to a small coil of wire, which I put in a beaker of oil. The oil gets hot. The reason is that the battery contains chemical energy. This is changed into electrical energy in the wires, and then into heat energy in the oil. This can be summarised:

chemical energy -> electrical energy -> heat energy

4. ‘Transfer of energy’

I connect up a battery to a small coil of wire, which I put in a beaker of oil. The oil gets hot. The reason is that the battery is a store of concentrated energy. Energy is transferred from the battery to the oil, where it is less concentrated. This makes it get hot.

## Activity B3 Comparing approaches (cont.)

The following statements are mainly about energy, with a few about the related concept of entropy. Which do you think are true and which do you think are false?

A Every change that happens involves an energy change.

B The First Law of Thermodynamics says that energy is neither created nor destroyed.

C Energy is the cause of change.

D Energy doesn't really exist, as it is just a value that can be calculated.

E The Second Law of Thermodynamics essentially says that at the molecular level things tend to get jumbled up or disordered.

F The Second Law of Thermodynamics does not apply to living things, but it does when they die and decay.

G In a spontaneous process entropy always increases.

H Entropy is a measure of how ordered a system is at the molecular level – the more ordered, the higher the entropy.

I When we exercise our bodies we use up energy.

J When we exercise our bodies we make energy.

## Activity B4 Energy from hot to cold

### *Aims*

- To introduce abstract pictures showing temperatures and energy flows.
- To use the abstract pictures in a matching activity to represent some everyday examples of energy flow from hot to cold.

### *Background*

The abstract pictures in this activity are intended to help pupils to focus on the idea that energy flows from hot to cold and that equilibrium is reached when temperatures become equal. Temperature is seen as a measure of the concentration of energy, so energy tends to spread out from where it is concentrated to where it is less concentrated. Thus this is similar to the process of diffusion, in which matter, rather than energy, spreads out.

There are a set of 3 OHTs which introduce the conventions used in the abstract pictures. Each section on the OHTs has a question for the class to discuss and answer. In each section, there is a reminder of the important points to bring out in the discussion. Discussion with pupils is helped by having equipment to demonstrate the situations (needed are a beaker of hot water, an ice cube and a metal block).

There follows an activity in which pupils need to use these abstract pictures to represent some everyday changes (‘Energy transfers in the kitchen’). This activity is best done as a small group activity, with discussion about the pictures, before pupils begin to write about the changes. Pupils should be encouraged to discuss the reasons why they make their selections, and there should be an opportunity for the whole class to discuss their selections after they have finished the activity.

### *What to do*

1. Read through each of the OHTs on pages 3, 4 and 5. Each picture shows an object and a background - the background represents the temperature of the room. The shading in these pictures shows how concentrated the energy is. Think about the question in each section and then turn to the notes about the section on page 2 which explains the conventions used. After you have done a few, you should begin to understand the conventions used and work out the answers before reading the notes.

2. The activity based on these abstract pictures is on pages 6 and 7. It is best to cut out the pictures on sheet 2 so that they can put these on the spaces on the worksheets before deciding on a final answer. Note that in some cases, the names of the boxes on the sheet have been deliberately omitted. For example, this has been done in part D in order that pupils must decide whether to represent ice cubes in the left-hand box and lemonade in the right-hand box, or vice versa.

3. After you have completed the activity, you can check your answers on page 2.

4. Now think back over these activities, and consider the following questions:

- Could you incorporate these activities into your current schemes of work?
- How would you adapt them?
- What aspects of these activities do you think are useful?
- What aspects of these activities do you think are unhelpful?

## Activity B4  Energy from hot to cold (cont.)

### *Energy on the move*

**Sheet 1 - A beaker of hot water cools down**

*A  Which shows a beaker of hot water best?*  Picture 1 shows something which contains concentrated energy (i.e. something hot).  The energy in the background is less concentrated (i.e. the room is cooler).

*B  Which shows the energy transfer best?*  Picture 2 shows energy flowing from where it concentrated to where it is less concentrated (i.e. from hot to cold).

*C  Which shows what happens best?*  Picture 2 shows that the water has cooled down so that it is now at the same temperature as the background.

**Sheet 2 - An ice cube melts in the room**

*A  Which shows an ice cube best?*  Picture 3 shows something which contains less concentrated energy that the background (i.e. something cold).

*B  Which shows the energy transfer best?*  Picture 1 shows energy flowing from the background to the ice cube. (Some children may think that it is *'cold'* that flows from the ice cube to the background.)

*C  Which shows what happens best?*  Picture 2 shows that after melting the water will end up at the same temperature as the background.

**Sheet 3 - A metal block is put in hot water**

We can make pictures which show what happens when there are two or more objects.

*A  Which shows the energy transfer best?*  Picture 2 again shows energy flowing from where it is hot to where it is colder.  Energy is transferred from the water to the metal.

*B  Which shows what happens best?*  Picture 2 shows that the water and the metal end up at the *same* temperature. One has cooled down and the other has warmed up.  The energy becomes spread out between the two.  (Both water and metal are now warmer than background - eventually they will cool down to the same temperature.)

### *Energy transfers in the kitchen: answers (from pages 6 and 7)*

A  2  ->  8
B  2 3  ->  10 10
C  5  ->  8
D  4 5  ->  11 11

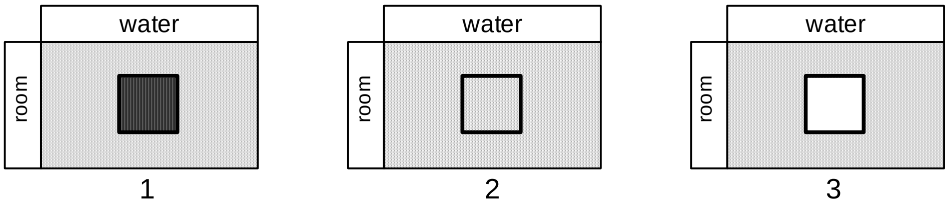
## Activity B4 Energy from hot to cold (cont.)

# Energy on the move

**Sheet 1**

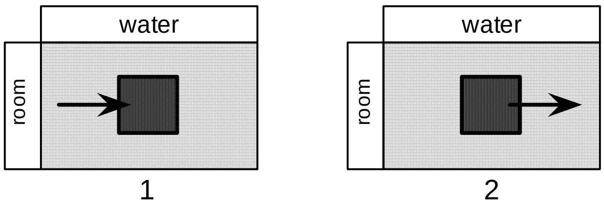
### A beaker of hot water cools down

**A** Which shows a beaker of hot water best?



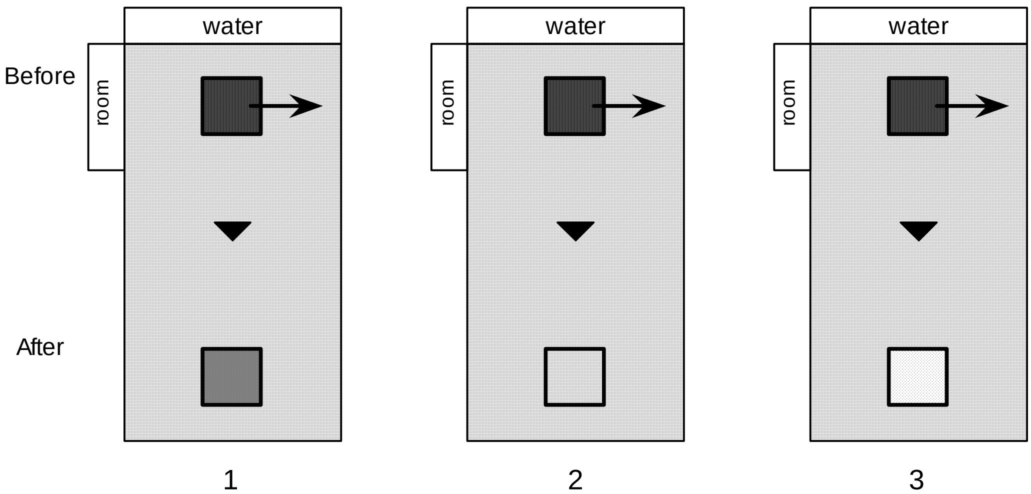

hot = high temperature = high concentration of energy = dark shading

**B** Which shows the energy transfer best?




energy goes from hotter to colder

**C** Which shows what happens best?




energy spreads out - concentration of energy becomes even - temperatures become equal

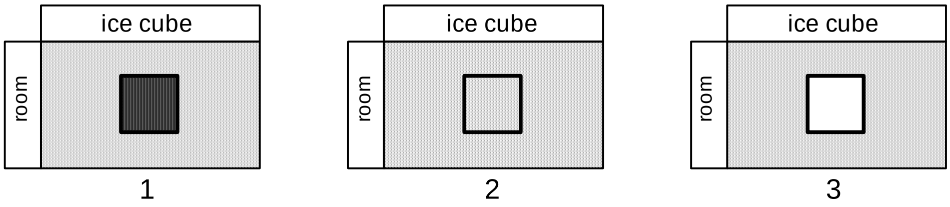
## Activity B4  Energy from hot to cold (cont.)

# Energy on the move

**Sheet 2**

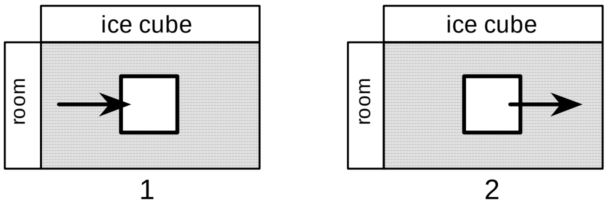
### An ice cube melts in the room

**A** Which shows an ice cube best?



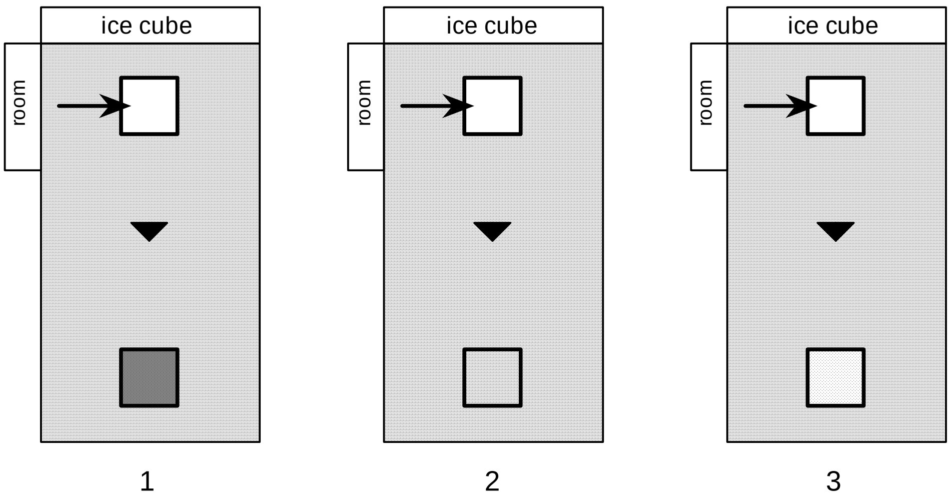

cold = low temperature = low concentration of energy = light shading

**B** Which shows the energy transfer best?




energy goes from hotter to colder

**C** Which shows what happens best?




energy spreads out - concentration of energy becomes even - temperatures become equal

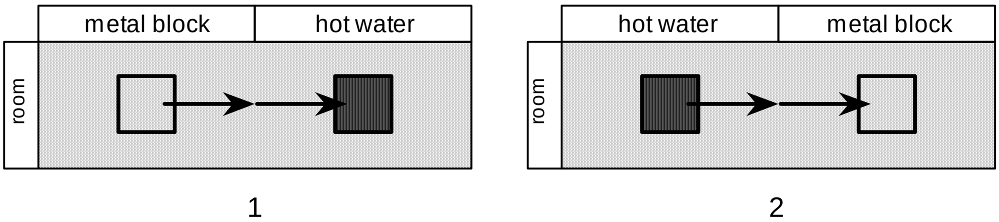
## Activity B4 Energy from hot to cold (cont.)

# Energy on the move

**Sheet 3**

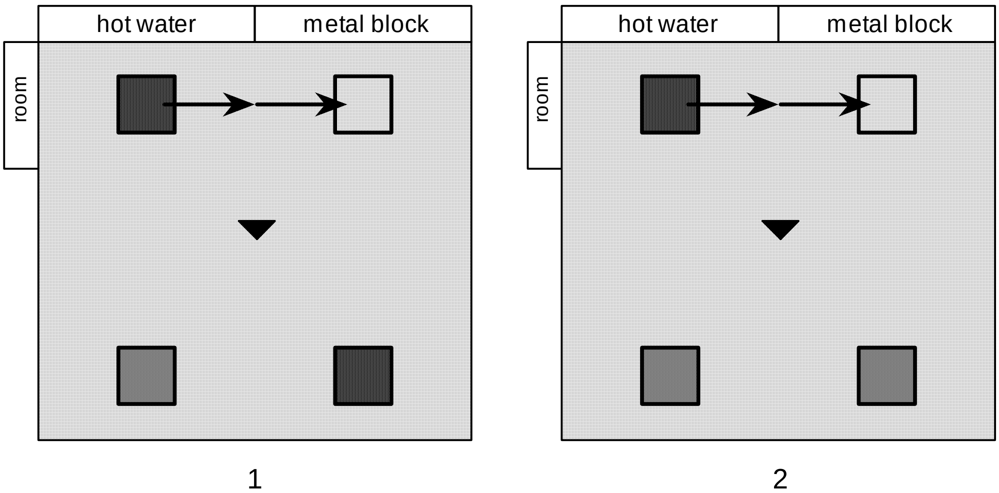
### A metal block is put in hot water

**A** Which shows the energy transfer best?




energy goes from hotter to colder

**B** Which shows what happens best?




energy spreads out - concentration of energy becomes even - temperatures become equal

## Activity B4 Energy from hot to cold (cont.)

## Energy transfers in the kitchen

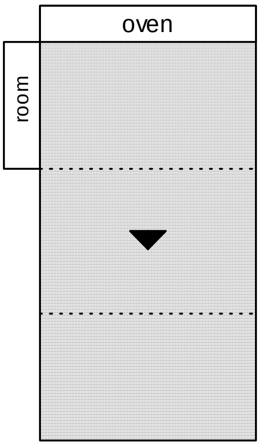
**Sheet 1**

In a kitchen, we can find lots of things at different temperatures. Energy goes from hot things to cold things.

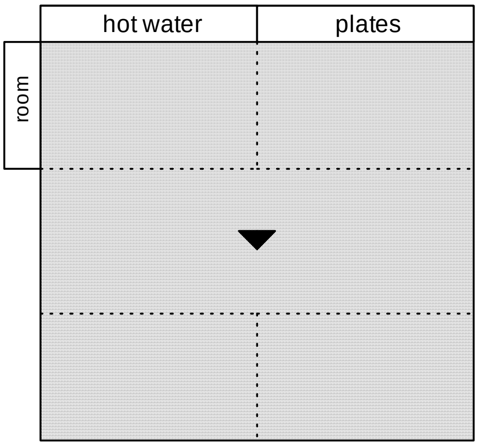
1 Below are some changes. Choose the pictures from sheet 2 you think are best to fill in the spaces. In some of the changes, you need to write in the labels at the top of the boxes.

2 When you have done all 4 changes, write about what the pictures show. You should explain where the energy is concentrated at the start, how the energy flows and where the energy is at the end.

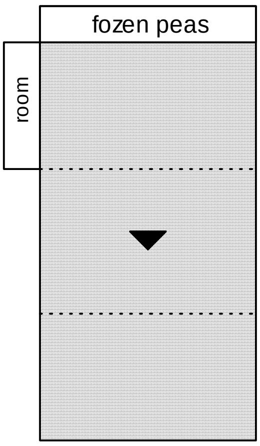
**A** a hot oven cools down



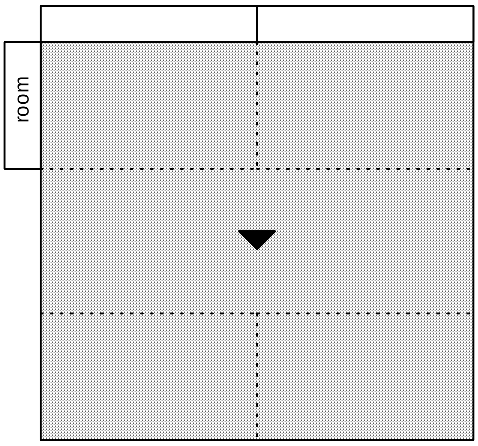

**B** some plates are put in hot washing-up water




**C** frozen peas left in a room



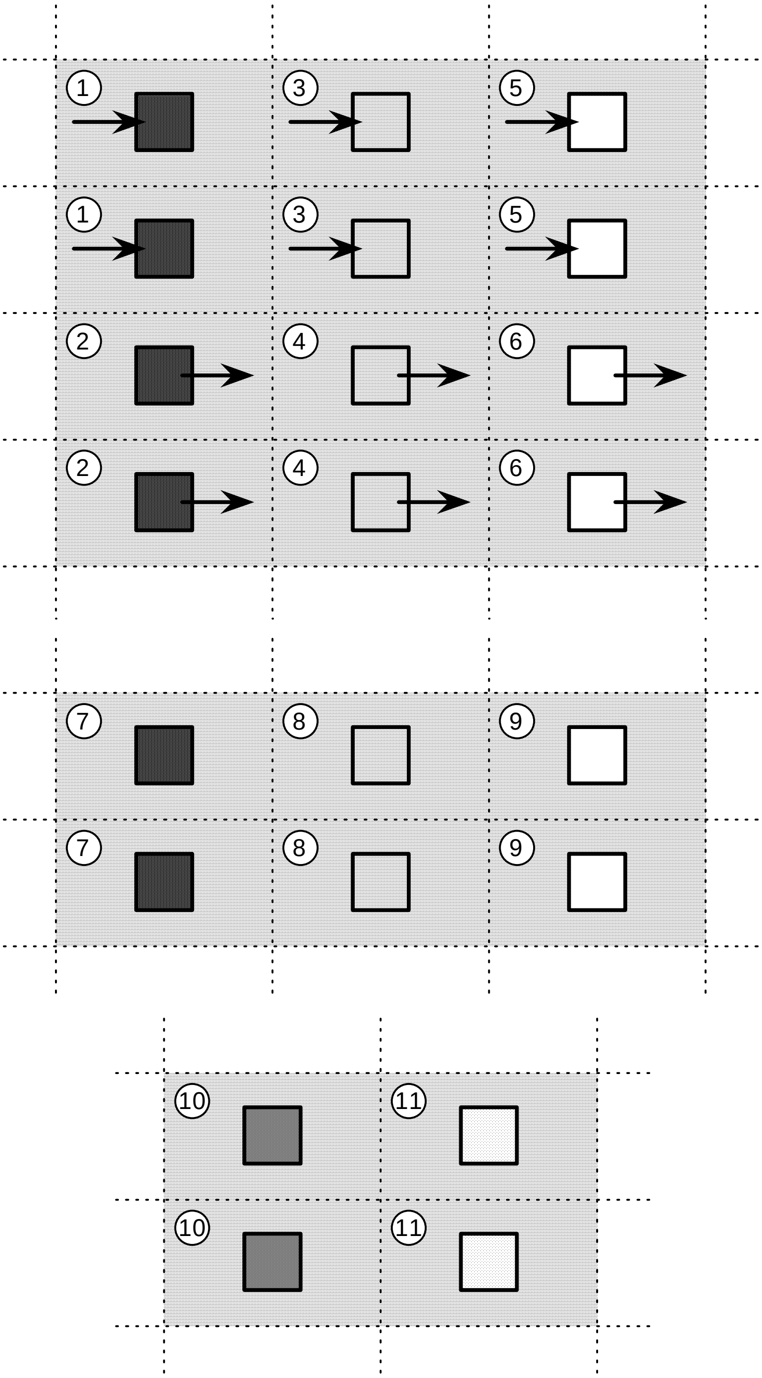

**D** some ice cubes are put in a glass of lemonade



## Activity B4 Energy from hot to cold (cont.)

**Energy transfers in the kitchen (continued)** **Sheet 2**

Cut out these pictures and match them to the spaces on sheet 1.



## Activity B5 Insulation

### *Aims*

- To provide practical experience in looking at the effect of insulation.
- To use the idea of energy flows due to temperature differences to explain the phenomena.
- To relate the ideas of energy flow and insulation to more familiar everyday examples, supported by the use of abstract pictures.

### *Background*

Pupils have little difficulty in believing that insulation will help to keep hot things hot. However, they may find it more difficult to see that it can help to keep cold things cold. Particularly puzzling may be that it does not affect something which is at room temperature. These practical activities explore these ideas.

The practical activity is followed by an activity in which pupils match situations involving insulation with abstract pictures of energy flow. It could be done as a poster activity, with each group writing reasons for their matches on the poster. They should cut up the sheets showing the abstract pictures and lay them out on the poster in the arrangement shown below, leaving spaces to match the situations against them. Having made their choices and written their reasons, the posters can form the basis for a class discussion.

Also included here are some examples of pupil discussion related to the activity on insulation, in order to give an idea of the range of understanding that might be expected.

### *What to do*

1. Read page 3 which describes the practical activity, and make predictions of the temperatures as explained on the sheet.

2. Typical values for each of the three pairs of tubes are $60^0$C and $50^0$C, $20^0$C and $20^0$C, $10^0$C and $15^0$C. Now try the questions on page 4. These are intended to encourage pupils to interpret these results by thinking about the direction and relative sizes of the energy flows due to temperature differences. The key idea here is that insulation is a barrier to energy flow. If you are doing this as a pupil activity, it may be useful to make this sheet up as an OHT for class discussion before they attempt the questions themselves.

3. Pages 5, 6 and 7 include an activity in which situations are matched against abstract pictures. This is to enable pupils to apply the ideas they have learnt in the practical activity in a range of everyday situations. Cut out each of the situations and the abstract pictures as described in the instructions, and match the situations to the abstract pictures. It is better to cut out the pictures rather than to make the matches directly from the sheets, since this encourages more discussion and it is easier to see the patterns that emerge.

4. When you have completed the making the matches, then check your answers on page 2. If you have matched more than one situation against one abstract picture, then think about what is similar between the two situations. Making abstractions and generalisations about what appear to be different kinds of situation is of fundamental importance in thermodynamic thinking.

5. On page 8, there are some examples of pupils discussing the activity using abstract pictures of insulation. Read what they say. How well do you think they understand the basic ideas about temperature differences, energy flows and insulation as a barrier. How well do they differentiate between concepts such as energy, heat and temperature? Can you identify any alternative ideas that they hold?

## Activity B5  Insulation (cont.)

### ***Examples of insulation: answers (from pages 5, 6 and 7)***

| | | |
|---|---|---|
| 1 A E H | 2 | 3 |
| 4 | 5 D F | 6 |
| 7 | 8 | 9 B C G |

Note that the situations have been selected to cover a range of cases, in which the insulated object is cooler, warmer or at the same temperature as the background, and in which the background may be cooler, warmer or the same as room temperature.  Also note that of the abstract pictures only 1, 5 and 9 show possible changes (2 and 8 are possible if you allow the existence of a perfect insulator).

## Activity B5 Insulation (cont.)

# Insulation

**Sheet 1**

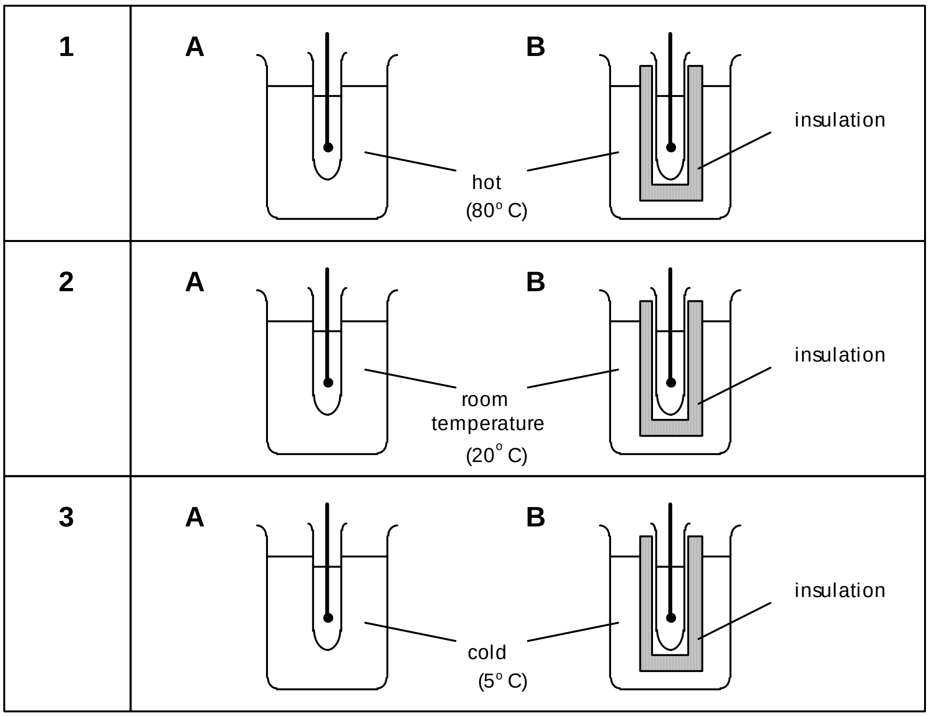
All of the pictures below show tubes containing water at 20°C. It is put into water at different temperatures, some with and some without insulation. Can you predict what will happen?

**Prediction** For each situation, predict what the temperature might be after 2 minutes. The first one has been done as an example.

Temperature at start: 20 °C

Temperature after 2 minutes

| | A | B |
|---|---|---|
| 1 | 60 °C | |
| 2 | | |
| 3 | | |




**Results** Now do the experiments and fill in this table.

Temperature at start: 20 °C

Temperature after 2 minutes

| | A | B |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

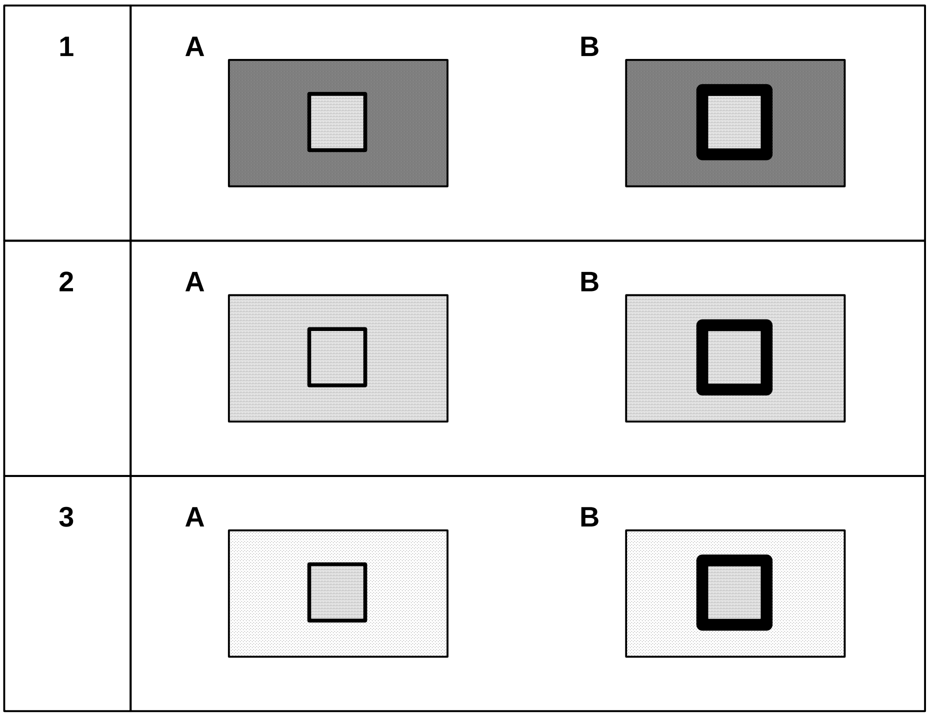
**Conclusion** What can you say from these results?

## Activity B5 Insulation (cont.)

**Insulation (continued)** **Sheet 2**

1 The pictures below represent the situations you set up in the experiment. Draw arrows on these pictures to show what is happening to the energy. Use arrows of different sizes to show how much energy is flowing:

a lot of energy flowing a little energy flowing




2 Now write about what each of these pictures is showing. You should include in your answers:

- where the energy is concentrated at the start
- which way the energy flows
- how much energy flows
- what happens to the temperatures

## Activity B5  Insulation (cont.)

# Examples of insulation

**Sheet 1**

1  On sheets 1 and 2 are 8 pairs of situations.  In each pair the first is without insulation, and the second is with insulation.

2  On sheet 3 are some pictures pictures representing these changes.  Cut them out and lay them out on a table.

3  Cut out each of these situations and match it against the picture you think is best.

### A   Hot chocolate left in a room

hot chocolate in a cup

hot chocolate in a vacuum flask

### B   Cold lemonade in a warm room

cold lemonade in a glass

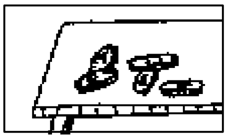
cold lemonade in a vacuum flask

### C   Frozen food

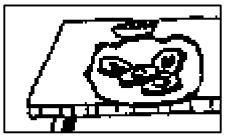
frozen food left on a table

frozen food wrapped in newspaper

### D   Coins at room temperature



coins at room temperature left on a table



coins at room temperature wrapped in a woollen bag

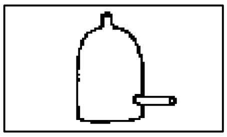
**Section B  Learning about the innovation** **Page 6 of 8**

## Activity B5  Insulation (cont.)

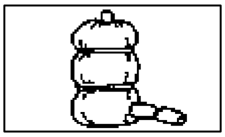
**Examples of insulation (continued)**

**Sheet 2**

### E  Hot water tank



hot water tank
without insulation



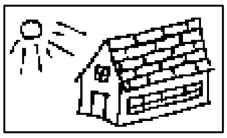
hot water tank
with insulation

### F  Snowman on a freezing day

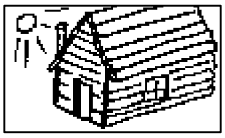
snowman on a
freezing day

snowman wrapped in a
coat on a freezing day

### G  Sun shining on a house

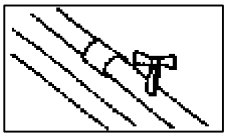


sun shining on a poorly
insulated house

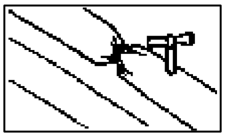


sun shining on a well
insulated house

### H  Water pipes on a cold day in winter



water pipes on
a cold day

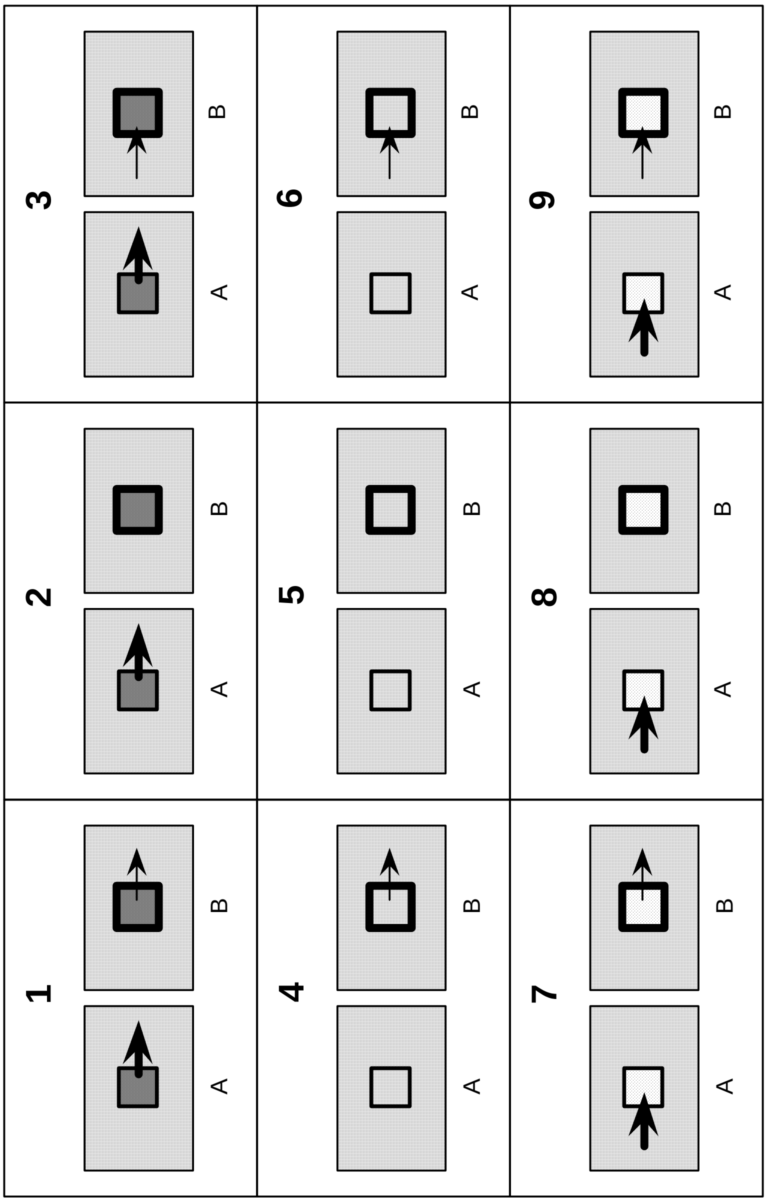


insulated water
pipes on a cold day

**Section B Learning about the innovation** **Page 7 of 8**

## Activity B5 Insulation (cont.)

**Examples of insulation (continued)** **Sheet 3**



## Activity B5  Insulation (cont.)

### *Examples of pupils' discussion*

The following examples are of 12-13 year-old pupils discussing the matches that they make to the abstract pictures while doing the activity described on pages 6 to 8.

*Hot chocolate:*
"The hot chocolate is hotter than the room temperature ... and when the hot chocolate is left in the room, 'cos the room is colder the energy goes out of it and the hot chocolate starts to get cold slowly."

*Frozen food:*
"Because the frozen food left on the table and the food is colder than the room and the room temperature melts the frozen food ... the energy is going into the food and makes it warmer."

*Frozen food:*
"The food is more colder so the room temperature will go into the food and the newspaper is not that powerful so the room temperature will slowly go into the newspaper wrapping the food."

*Hot chocolate:*
"The hot chocolate is hotter than the room temperature so this *(the central region in the representation)* is darker *(i.e.  hotter with energy more concentrated)* and when the hot chocolate is left in the room, because the room is colder the energy goes out of it *(the chocolate)* and the hot chocolate starts to get colder slowly.  This one in here *(in the vacuum flask)* - the hot chocolate is still hotter than the room so it's darker but it stays the same, as it's in the vacuum flask so no heat will come out and no heat will come in."

*Cold lemonade:*
*One choice of picture:*
"It's colder on the inside, and then the energy from the heat on the outside is going in making it warmer, and when it's in the vacuum flask the coldness just escapes making it warmer."
*A different choice of picture:*
"Mine's the same really but the cold doesn't escape - the insulation makes the lemonade warmer."
"That's what I meant - the insulation makes it warmer."
"No but that means if the insulation made it warmer the cold wouldn't go out but the heat would come in - so the heat goes in not comes out."

## Activity B6 Things that 'just happen' and things that don't

### *Aims*

- To introduce the idea of spontaneous and non-spontaneous changes, and the abstract pictures to represent them.
- To develop the key idea that spontaneous changes are those that 'just happen' by themselves and are able to drive other changes which do not 'just happen' by themselves.

### *Background*

Pupils seem to take quite easily to the phrases 'changes that just happen by themselves' and 'changes that do not just happen by themselves', so these terms are used widely in the *Energy and Change* materials. The essential idea here, which is built on later in later activities, is that changes which 'just happen' can drive those which do not. Energy is often involved in changes, but in thinking about causes for changes, the focus is on spontaneity rather than on the incorrect explanation that 'energy drives changes'.

### *What to do*

1. Read page 3 which is intended to be used as an OHT to introduce the ideas. The first abstract picture on this sheet uses the convention showing energy flowing from hot to cold and an equilibrium being established. This should be familiar from previous activities. The second and third pictures have not been met before here, though pupils using the *Energy and Change* materials would have come across them before. The second picture represents a moving object (with friction) slowing down as energy spreads out into the surroundings. The third picture represents the particles of two different substances becoming mixed together.

2. Do the pupil activity on page 4, in which changes are matched against abstract pictures. The changes are about things warming and cooling, and starting to move and stopping. If you are doing this with pupils, this would be a useful opportunity to give them practical experiences of moving things getting warmer, and to discuss what is happening to the energy when moving things slow down. The energy is 'spreading out' and the surroundings warm up.

3. After you have done the matching activity, check your answers on page 2.

4. On page 5, there is a further activity for pupils, in which they need to identify pictures which do not make sense. Do this activity, and check your answers on page 2.

5. On page 6, there are some examples of statements made by 13-14 year-old pupils explaining the meaning of these abstract pictures. Read what they say. How well do you think they understand the basic ideas about changes that 'just happen' and those that don't, and about coupled changes?

## Activity B6  Things that 'just happen' and things that don't (cont.)

### *Answers (from page 4)*

1 C  2 F  3 A  4 B
5 D  6 E

### *Answers (from page 5)*

Pictures 2 and 4 do not make sense, since the two changes (getting hotter and starting to move) do not 'just happen by themselves' as shown.  Picture 6 does not make sense, since it shows a change which does not 'just happen' to drive another.

**Section B Learning about the innovation** **Page 3 of 6**

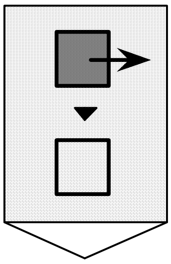
## Activity B6 Things that 'just happen' and things that don't (cont.)

### Things that 'just happen' and things that don't

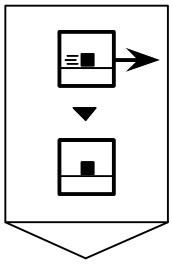
**Sheet 1**

**Some changes 'just happen' by themselves:**

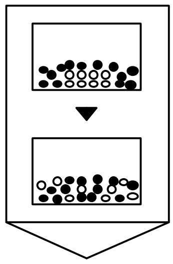
a beaker of hot water cools down



a moving ball slows down and stops



salt dissolves in water

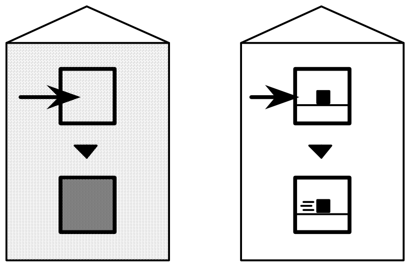


These pictures have been drawn with a box around them pointing down - this is to show that the changes 'just happen'.

**Some changes do not 'just happen':**

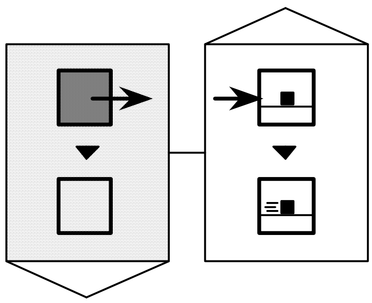
For example, things do not suddenly get hot or start moving for no reason:

Each of these pictures has a box around it pointing up - this is to show that the change does not 'just happen'.



However, we can use a change that 'just happens' to drive a change that does not.

For example, a steam engine - the engine moves because the hot steam cools.

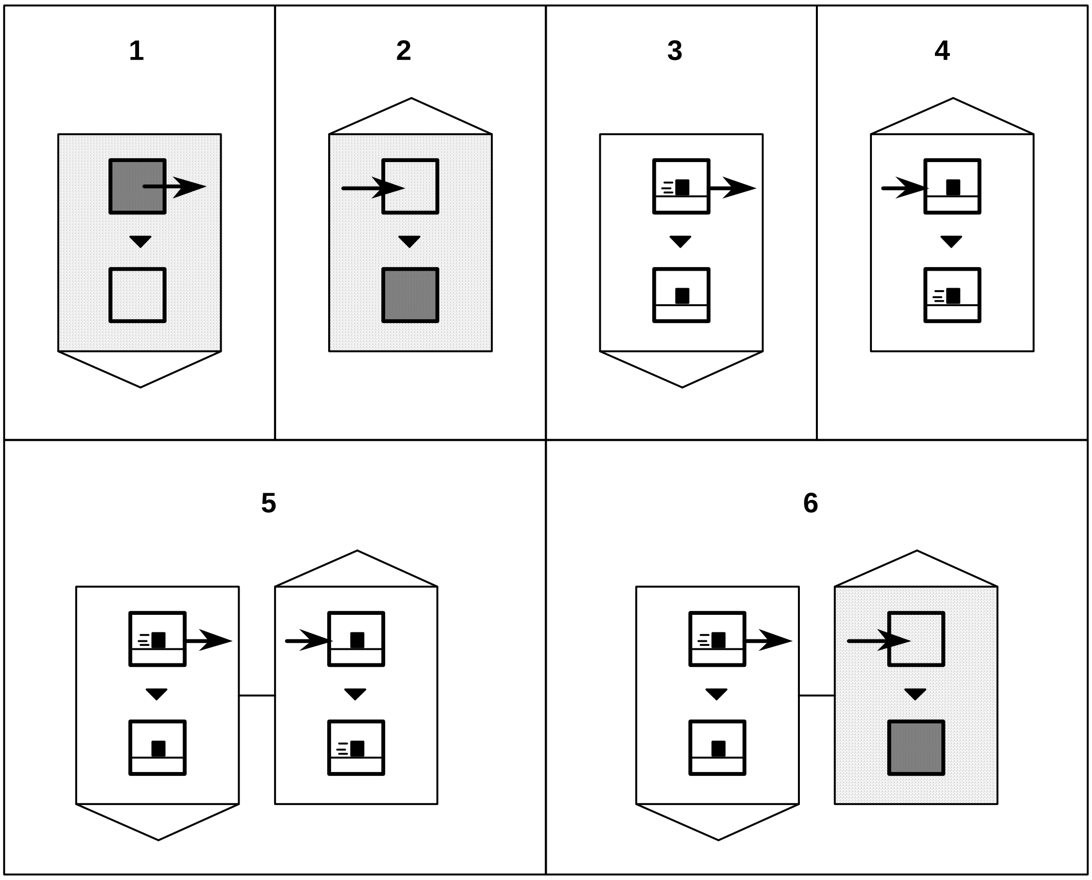


## Activity B6 Things that 'just happen' and things that don't (cont.)

## Things that 'just happen' and things that don't **Sheet 2**

1 Below are some different changes. Match each one to the picture you think best represents the change. (There is one change for each of the six pictures.)

| | |
|---|---|
| **A** If you stop pedalling a bicycle it will slow down and stop. | **B** A ball does not start moving just by itself. |
| **C** A hot cup of tea cools down. | **D** A tennis racquet hits a ball - the racquet slows down and the ball speeds up. |
| **E** When you use the brakes on a car, they get hot as the car slows down. | **F** A saucepan of water does not suddenly become hot for no reason. |



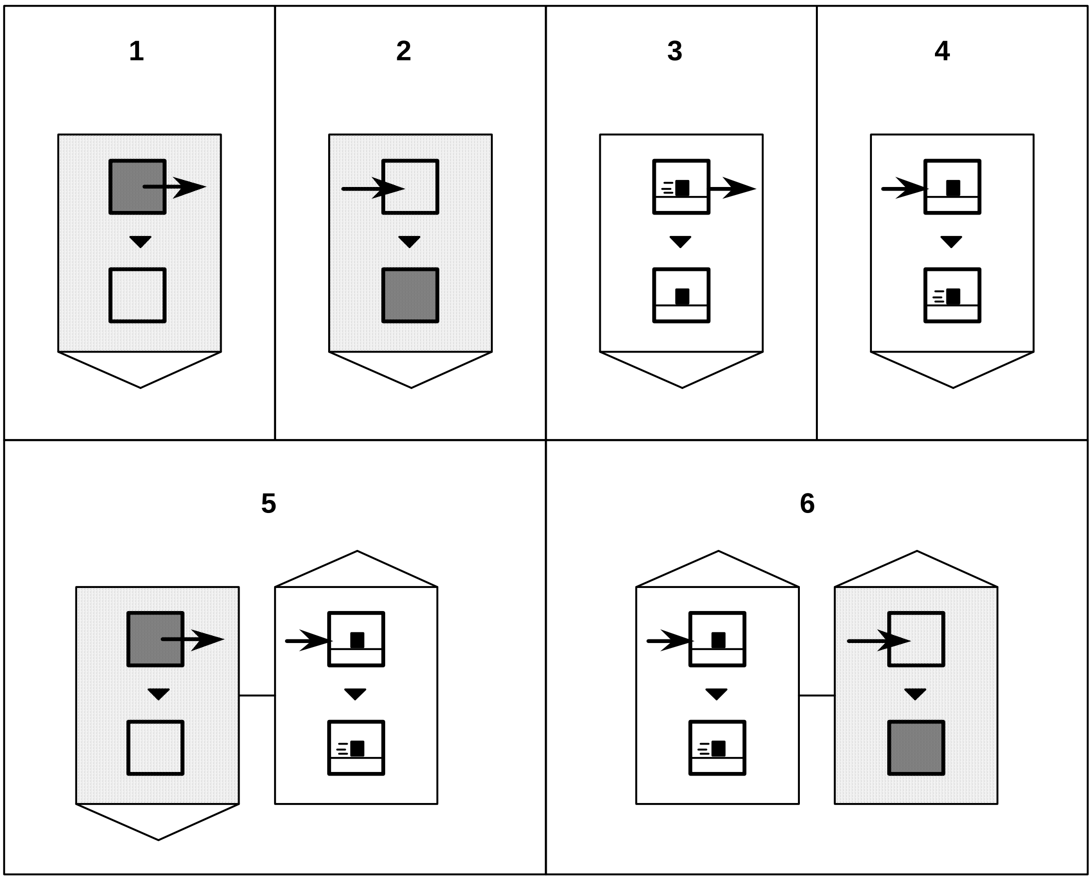
## Activity B6 Things that 'just happen' and things that don't (cont.)

**Things that 'just happen' and things that don't (continued)** **Sheet 3**

2 Below are some pictures representing changes. Some of these pictures do not make sense.

a) Which pictures don't make sense? Why not?

b) Which pictures do make sense? For each one, think of an example of what it could be showing.



## Activity B6 Things that 'just happen' and things that don't (cont.)

### *Examples of pupils' discussion*

The following are examples of statements made by 13-14 year-old pupils explaining the meaning of abstract pictures showing changes that 'just happen' and those that don't.

*Hot object spontaneously cools as energy flows from it to the cooler surroundings:*
"Something hot losing energy - getting cold."
"This is a room and this is a block and it is giving heat to the room and becoming the same temperature as the room."
"This happens usually, naturally."
"It just happens normally."

*The reverse change:*
"It's showing taking energy in."
"This is an example right. There is a glass of water and to make it hot just wouldn't happen."
"It does happen, but it is difficult to make it happen."
"It doesn't happen naturally but people ... You can make it happen."

*Objects slowing down and speeding up:*
"Something that is going fast and then slows down."
"Something starts moving."
"Natural and ... "
"One works - that one - and that one doesn't usually happen."
"Poltergeist!"
"Something that is moving and that is slowing down - stopping."
"Could be the wind that is pushing it or it just happens."

*Coupled changes:*
"This is the argument that it's possible, yeah? So you use something that is possible to make something that is impossible possible!"
"The 'down' one is something that happens and the 'up' one is - someone has to make it happen."

**Section B Learning about the innovation** **Page 1 of 7**

## Activity B7 Storing energy

### *Aims*

- To introduce what happens when springs are pulled and released.
- To draw the similarity between stretching a spring and lifting something away from the Earth.
- To compare releasing a spring or dropping an object to the burning of fuels as the coming together of fuel and oxygen that have been 'kept apart'.

### *Background*

The first part of this activity draws the similarity between pulling a spring and lifting something away from the Earth. It develops the idea that 'pulling apart' changes do not 'just happen' but that the opposite change does. However, when we say that these changes 'just happen' we need to add 'once they have been started' because there may be something preventing the change from happening. (For example, a ball at the top of a hill may need a push before it starts rolling down by itself.)

The second part of the activity extends the idea of a ‘spring’, so that fuel/oxygen systems can be thought of as ‘chemical springs’. An important idea here is that energy is released when a fuel *reacts with oxygen*. A fuel on its own is not a store of energy - a candle would be useless in outer space and a car would not work on the Moon because there is no oxygen. They would be useful as fuels if there was a supply of oxygen as well. (On a planet in which the atmosphere was methane, then oxygen would be a 'fuel'). Fuel burning in oxygen releases energy - this is similar to a spring being released.

Another important idea is that a fuel burning is *a change that 'just happens'*. Children may object to this idea, saying that you need to light it first. They are absolutely right - what we really mean when we say that fuel burning 'just happens' is that it 'just happens once is has been started'. This is just the same idea as giving a ball on a hill a push to start it rolling.

### *What to do*

1. Read through the OHTs on pages 3 and 4. so the same picture can be used to represent these changes. The similarity between mechanical and ‘gravitational’ springs is emphasised by using the same abstract picture to represent them. In using this activity with pupils, it is useful to discuss examples of other similar changes, e.g. squashing a spring, pulling and releasing a luggage cord or a rubber band, a rocket being fired into space, a falling meteorite.

2. Do the activity on page 4. Note that in this activity there is room for interpretation in the matches that could be made. Check your answers against those on page 2.

3. Read the OHT on page 6 which extends these ideas to the burning of fuels, and do the activity on page 7. Check your answers on page 2.

4. Now think back over these activities, and consider the following questions:

- Could you incorporate these activities into your current schemes of work?
- How would you adapt them?
- What aspects of these activities do you think are useful?
- What aspects of these activities do you think are unhelpful?

## Activity B7 Storing energy (cont.)

### *Springs and things: answers (from page 5)*

| | |
|---|---|
| 1 F 2 E | 3 B |
| 4 A C H | 5 D G |

### *Storing energy: answers (from page 7)*

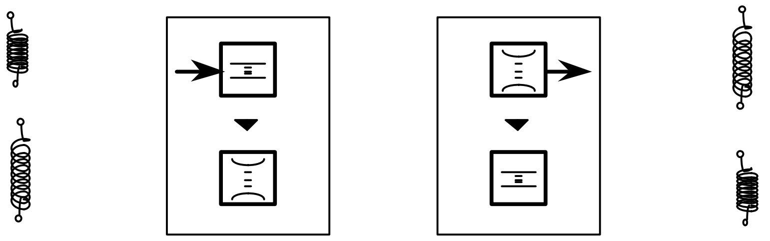
All of the changes which 'just happen' are those in which energy is released (it 'spreads out' and becomes 'less concentrated'). All of the changes which 'do not just happen' are those in which energy is stored.

## Activity B7  Storing energy (cont.)

## Springs and things

**Sheet 1**

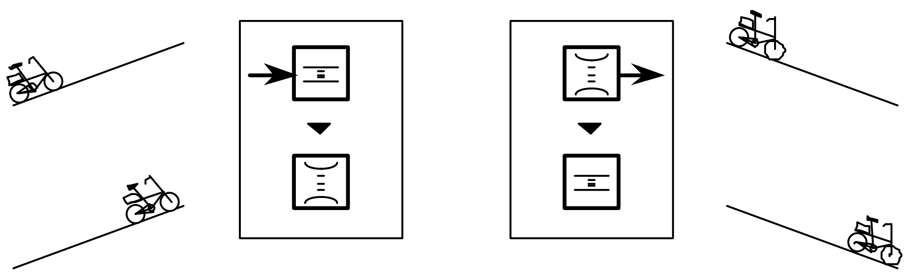
### A  Pulling a spring



When you pull the two ends of a spring apart, energy is stored.

When you 'let go' of the spring, the energy escapes and spreads out.  The spring and the air around it warm up a little.

### B  Pulling something away from the Earth



When you push a bicycle up a hill, it is a bit like pulling the two ends of a spring apart - you are 'pulling the bicycle and the Earth apart'.

When the bicycle runs down the hill, the energy escapes and spreads out.  The bicycle and the air around it warm up a little.

**Section B Learning about the innovation** **Page 4 of 7**

## Activity B7 Storing energy (cont.)

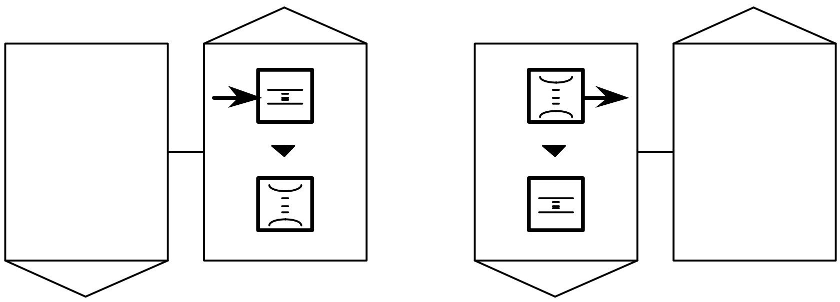
**Springs and things (continued)**

**Sheet 2**

### C Things that 'just happen'

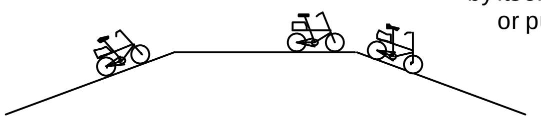
These kinds of changes do not 'just happen' by themselves. They need to be driven by other changes.

These kinds of changes 'just happen' by themselves ( ... once they have been started). They can drive other changes.



E.g. a bicycle does not go uphill by itself.

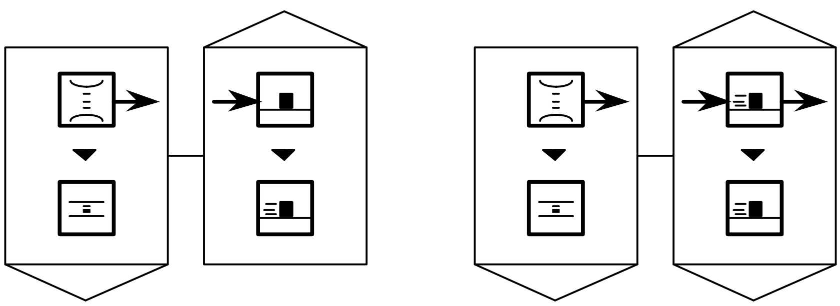
E.g. a bicycle goes downhill 'by itself' ( ... once you let go or push it over the edge).



### D Getting something moving and keeping it moving

A change which 'just happens' can be used to *get* something moving.

A change which 'just happens' can be used to *keep* something moving.



E.g. the spring in a clockwork toy starts to move it along the floor.

E.g. the spring in a clockwork toy keeps it moving along the floor.

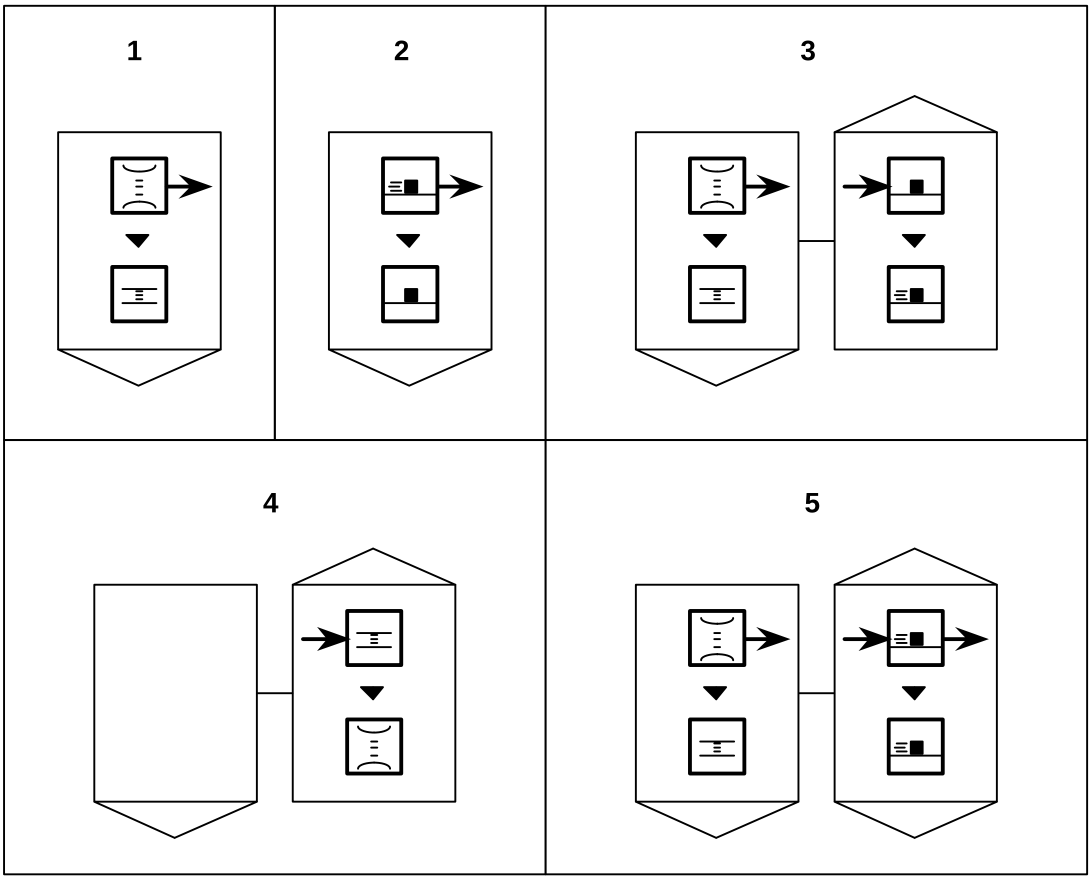
## Activity B7 Storing energy (cont.)

## Springs and things

**Sheet 3**

Below are some different changes. Match each one to the picture you think best represents the change. (You can match more than one change to a picture.)

| | | | |
|---|---|---|---|
| **A** | A clockwork toy is wound up. | **B** | A stretched bow is released, firing an arrow. |
| **C** | Water is pumped to the top of a hill. | **D** | A clockwork toy is running along the floor. |
| **E** | A ball is rolling along the ground and stops. | **F** | An old building falls down. |
| **G** | Water flowing down a river keeps a waterwheel turning. | **H** | Someone lifts a bucket to the top of a building. |



**Section B Learning about the innovation** **Page 6 of 7**

## Activity B7 Storing energy (cont.)

### Storing and releasing energy

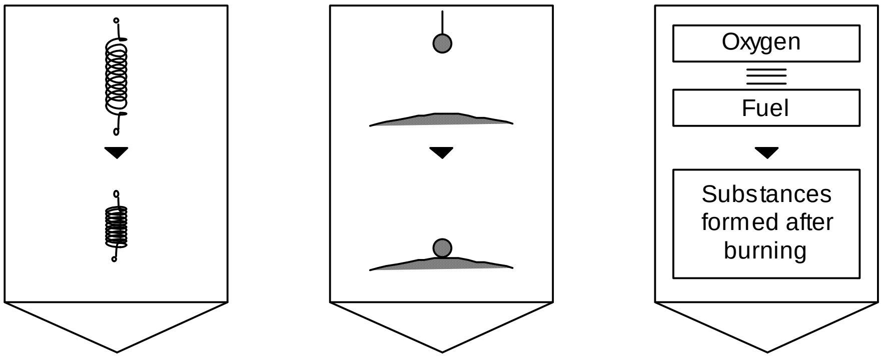
**Sheet 1**

**Energy stores**

a stretched spring - the two ends are being kept apart

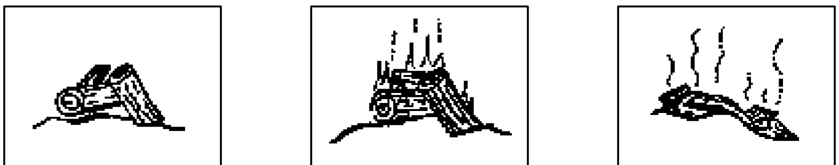
a ball above the ground - the ball and the Earth are being kept apart

a fuel in air - the fuel and the oxygen are being 'kept apart'

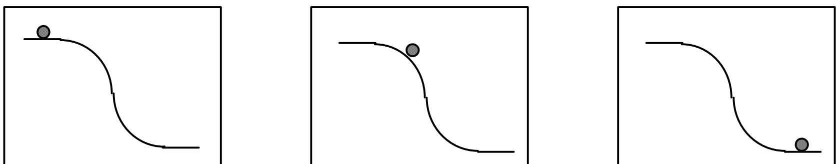



Could you light a candle in outer space? Could you run a car on the Moon? Could you light a match under water?

**Fuel burning in air 'just happens' by itself ... once it has been started**


wood in air — wood burning — after burning

wood burns in air 'just by itself' - though you may need to 'give it a push' (by making it hot) to get it started

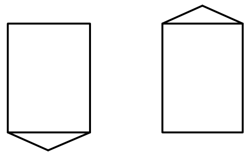

ball at top of hill — ball rolling — ball at bottom

a ball rolls down a hill 'just by itself' - though you may need to 'let it go' or 'give it a push' to get it started

## Activity B7 Storing energy (cont.)

# Storing and releasing energy

**Sheet 2**

| Here are some changes. Tick the boxes you think describe what happens in each change. | Is energy being stored? Or is energy being released?<br>stored released<br> | | Is the change something that 'just happens' (once started)? Or is it something that 'does not just happen' by itself?<br>'just happens' 'does not just happen'<br> | |
|---|---|---|---|---|
| A A clockwork toy is running along the floor. | ☐ | ☐ | ☐ | ☐ |
| B A candle burns with the oxygen in the air. | ☐ | ☐ | ☐ | ☐ |
| C A stretched bow is released, firing an arrow. | ☐ | ☐ | ☐ | ☐ |
| D Coal is burnt in a power station. | ☐ | ☐ | ☐ | ☐ |
| E Petrol is mixed with air in a car engine and burnt. | ☐ | ☐ | ☐ | ☐ |
| F A clockwork toy is wound up. | ☐ | ☐ | ☐ | ☐ |
| G A battery is recharged. | ☐ | ☐ | ☐ | ☐ |
| H Water is pumped up a hill. | ☐ | ☐ | ☐ | ☐ |

1 Which are the changes which 'just happen' - energy being stored or released?

2 Which are the changes which 'do not just happen' - energy being stored or released?

3 Could you light a candle in outer space? Could you run a car on the Moon? Could you light a match under water?

# Activity B8  Fuels and food

## *Aims*

- To explore the differences between using an electrical current to make water hotter and to electrolyse it.
- To use this example to introduce abstract pictures showing energy being stored and released during chemical change.
- To apply these ideas to examples involving the use of fuels and foods.

## *Background*

The pictures introduced here are probably the most difficult so far, since they are not just representing familiar changes in a new way (e.g. a hot object cooling or a moving object slowing down).  They require pupils to look at a change in a completely new way.  The essential idea is that energy can be stored by *making molecules move faster* or *by splitting molecules apart*.  The particular example chosen is water, and this can be accompanied by practical demonstration.  Using a power pack to drive the changes, water may be made hotter, or electrolysed to form hydrogen and oxygen.  These are both ways of storing energy.  Each of the reverse processes 'just happens' and can be used to drive other changes.  (*N.B.  A mixture of hydrogen and oxygen is explosive and needs to be handled with great caution.*  It must never be put into a container.)  A soap bubble containing the gases may be exploded - it makes a very loud bang - and strongly suggests the idea of energy being released as the 'pulled apart' oxygen and hydrogen join back together.

## *What to do*

1.  Read through the OHTs on pages 3, 4 and 5 which introduce the ideas. The first OHT summarises the changes, the second looks at what is happening in terms of particles and the third looks at what is happening in terms of energy. A commentary on these changes is given on page 2.

2.  Do the activity on page 6 by matching the changes to the pictures and check your answers on page 2.  Discuss the questions on this page in your group. In doing this activity with pupils, it is helpful to discuss with pupils in what ways changes A and B are similar and in what way they are different. What would you say? What are the similarities and differences between changes C and D?

3. Page 7 shows a set of changes in which energy is being stored or released (things warming and cooling, starting to move and stopping, and energy being stored or released during chemical change). Match these change to the appropriate abstract pictures on page 8. Then check your answers on page 2.

4.  On page 9, there are some examples of statements made by 13-14 year-old pupils discussing the activity on pages 7 and 8. Read what they say. How well do you think they understand the ideas about energy being stored and released during chemical changes? What ideas do they seem to find difficult?

## Activity B8 Fuels and food (cont.)

### *Ways of storing energy*

**A Storing energy by making something hotter (e.g. immersion heater in water)**

- We can store energy in water by making it hotter - making the particles move faster.
- This does not happen 'by itself' - need something to make it happen, to drive the change (in this case - a power pack)
- 

**B Storing energy by 'hiding it away' (e.g. electrolysis of water)**

- Making water hot is not the only way can use it to store energy - we can also use store energy by *pulling* the molecules of water apart (the atoms in the molecules are attracted to each other). This is like storing energy in a *spring* by pulling it apart - the energy does not make the water hotter, the energy is 'hidden away' like in a stretched spring. Pulling apart water molecules gives hydrogen and oxygen.
- This does not happen 'by itself' - need something to make it happen, to drive the change (in this case - a power pack)

**C Energy escaping by cooling down (e.g. hot water cools after being heated with immersion heater)**

- Energy escapes when the water cools down - the particles slow down.
- This 'just happens by itself' - we can use it to drive other changes (for example, making something hot or making something move)

**D Energy escaping by releasing energy that was 'hidden away' (e.g. hydrogen and oxygen react together to form water)**

- Energy escapes when the hydrogen atoms and oxygen atoms rejoin to form water - like a *spring* being released - the energy 'hidden away' in the hydrogen and oxygen now spreads out.
- This 'just happens by itself' - we can use it to drive other changes, for example, making something hot or making electricity).

### *Ways of storing energy: answers (from page 6)*

A 1 B 3 C 2 D 4

### *Fuels and food: answers (from pages 7 and 8)*

1 H 2 A C
3 E G 4 B D
5 J 6 F I

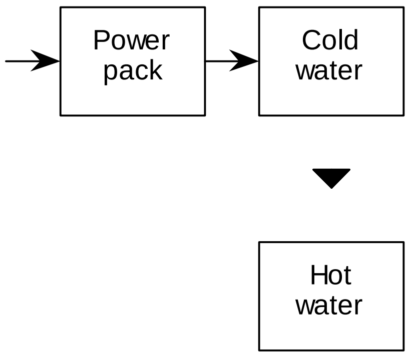
## Activity B8 Fuels and food (cont.)

### Ways of storing energy

**Sheet 1**

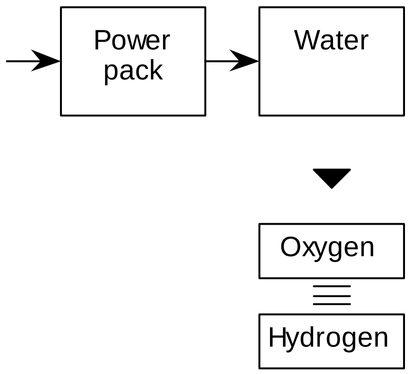
**A Storing energy 1**

Water is heated with an immersion heater.



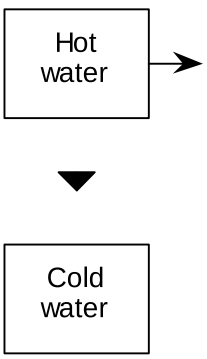

**B Storing energy 2**

Water is electrolysed to give hydrogen and oxygen.



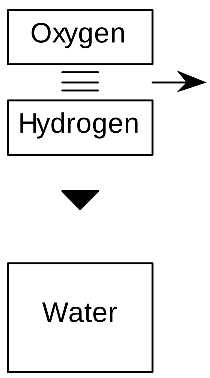

**C Energy escaping 1**

Hot water is left to cool.




**D Energy escaping 2**

Hydrogen and oxygen react to form water.



**Section B Learning about the innovation** 

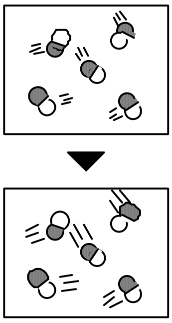
## Activity B8 Fuels and food (cont.)

**Ways of storing energy (continued)**

**Sheet 2**

### A Storing energy 1

**- by making something hotter**

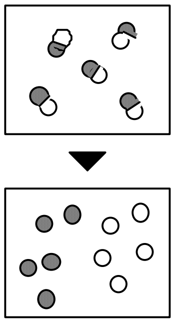


particles move faster

(e.g. water is heated with an immersion heater)

### B Storing energy 2

**- by splitting particles**

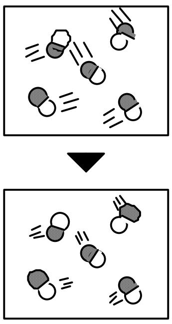


pulling particles apart

(e.g. water is electrolysed to give hydrogen and oxygen)

### C Energy escaping 1

**- by cooling down**

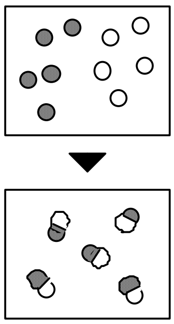


particles move slower

(e.g. hot water is left to cool)

### D Energy escaping 2

**- by particles joining**



particles forming again

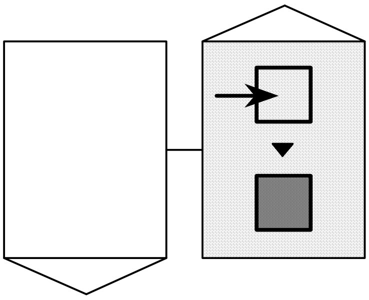
(e.g. hydrogen and oxygen react to form water)

## Activity B8 Fuels and food (cont.)

**Ways of storing energy (continued)** **Sheet 3**

### A Storing energy 1

**- by making something hotter**

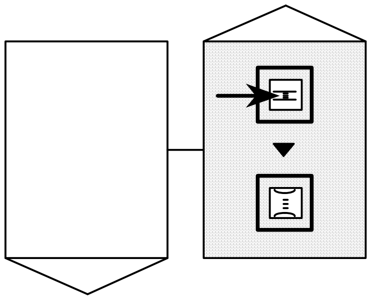


does not 'just happen'
needs to be driven

(e.g. water is heated with an immersion heater)

### B Storing energy 2

**- by 'hiding it away'**

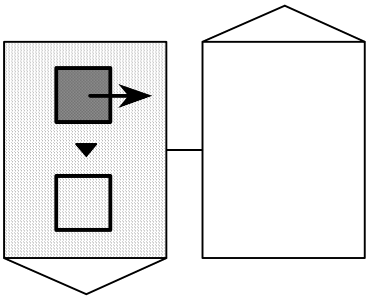


does not 'just happen'
needs to be driven

(e.g. water is electrolysed to give hydrogen and oxygen)

### C Energy escaping 1

**- by cooling down**

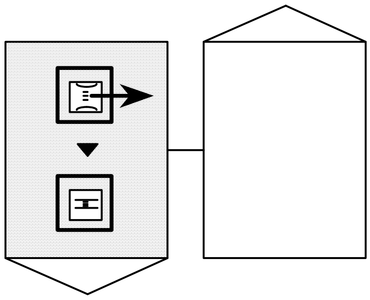


'just happens'
can drive another change

(e.g. hot water is left to cool)

### D Energy escaping 2

**- by releasing energy that was 'hidden away'**



'just happens'
can drive another change

(e.g. hydrogen and oxygen react to form water)

## Activity B8 Fuels and food (cont.)

# Ways of storing energy

**Sheet 4**

The pictures below show some ways of storing and releasing energy. Two ways of storing energy are shown:

- by making something hotter (the particles move faster)
- by 'hiding it away' (the particles are pulled apart).

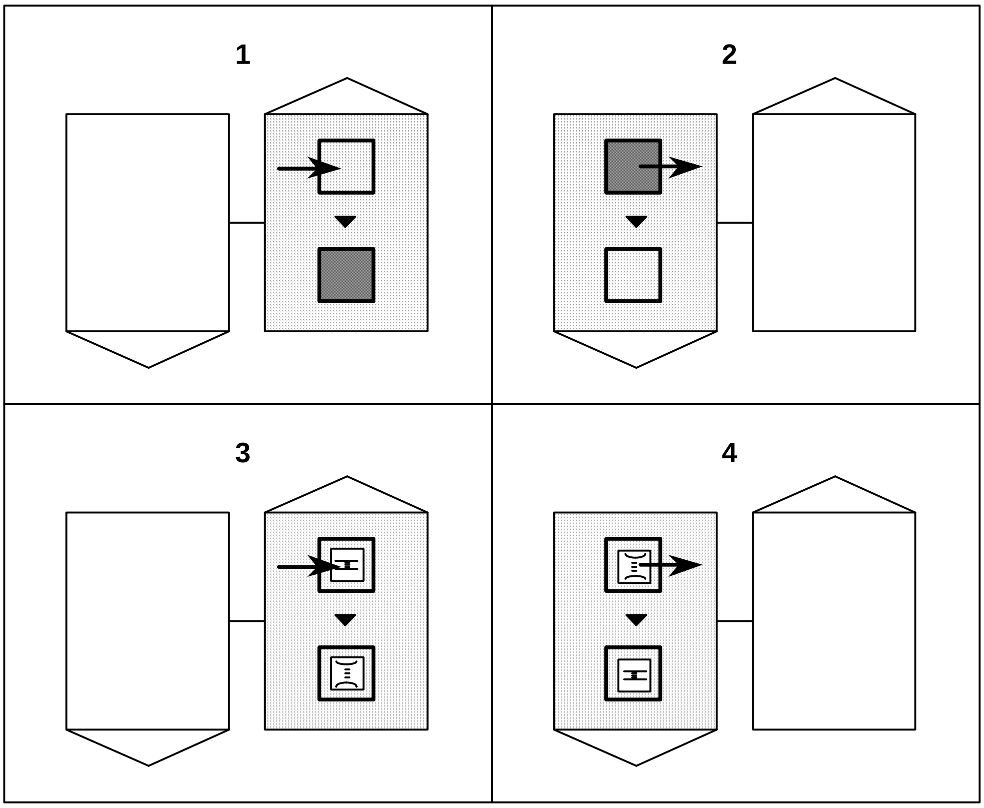
Match each of these changes to the the picture you think is best.

A Water is heated with an immersion heater
B Water is electrolysed to give hydrogen and oxygen
C Hot water is left to cool
D Hydrogen and oxygen react to form water

**Questions**

For each of the above changes, answer these questions:

1 What happens to the energy?
2 What happens to the particles?
3 Does the change 'just happen' by itself or does it need to be 'driven' by another change?

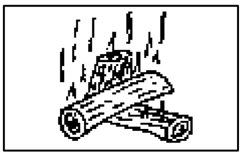
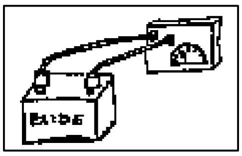
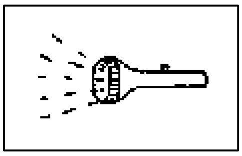
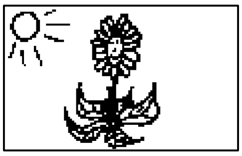
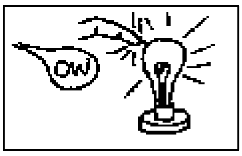
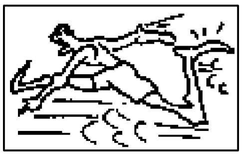
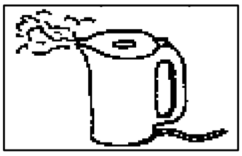
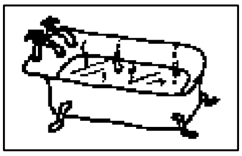
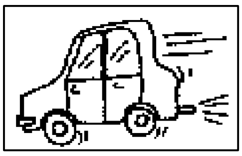
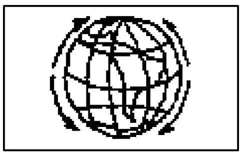


## Activity B8  Fuels and food (cont.)

## Fuels and food

**Sheet 1**

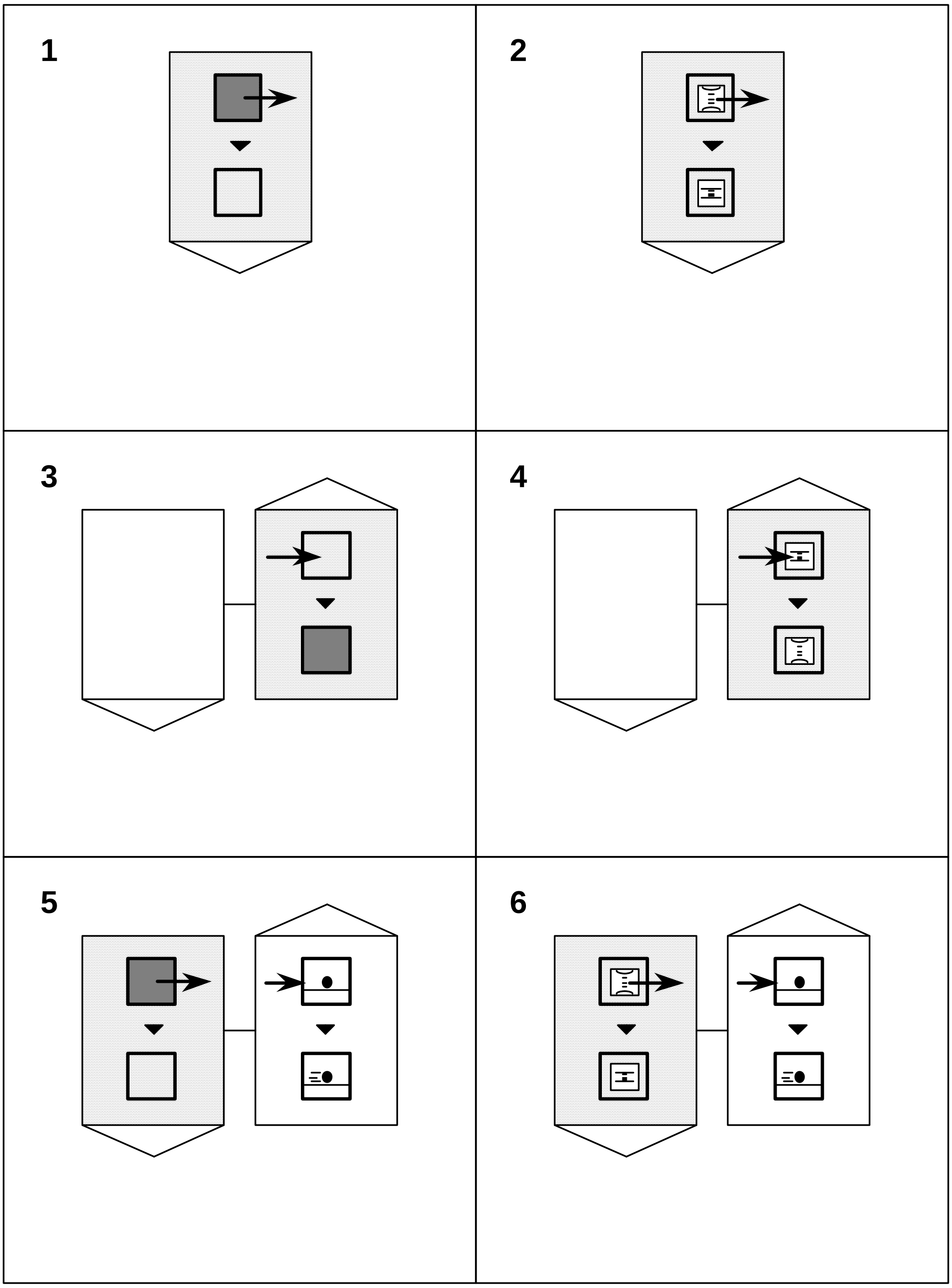
Below are some different changes.  Match each one to the picture you think best represents the change.  (You can match more than one change to a picture.)

| | |
|---|---|
| **A**  wood burning | **B**  recharging a battery |
| **C**  a torch battery runs down | **D**  a plant makes starch by photosynthesis |
| **E**   an electric light bulb gets hot | **F**  a person uses up food running a race |
| **G**  using a kettle to boil some water | **H**  a bath of hot water cools down |
| **I**  petrol is used in a car engine | **J**  winds blow because energy goes from hot regions of the Earth to cold |

**Section B  Learning about the innovation** **Page 8 of 9**

## Activity B8  Fuels and food (cont.)

**Fuels and food (continued)** **Sheet 2**




Energy and change Sheet H5/2

## Activity B8  Fuels and food (cont.)

### *Examples of pupils' discussion*

The following are examples of statements made by 13-14 year-old pupils discussing the activity on pages 7 and 8 in which changes involving energy being stored and released are matches to abstract pictures.

Matching situations to abstract pictures:

*Torch battery:*
"Like something happens by itself ... so ... it's from stored to released.
"Because energy was inside and it went outside."

*Bath cooling:*
"Because it goes from hot to cold, and it's heat and energy is being released."

*Petrol used in a car:*
"Because it's stored and then it's released which makes the car move."

*Light bulb:*
"Someone's driving that to get hot."

*Person running:*
"Number 6 then, because that's like pulling chemicals and things (6), and this is just cooling down (5)."

Finding similarities between situations matched to the same abstract picture

*An electric light bulb gets hot / Using a kettle to boil some water:*
"Energy is being stored up "
"Something is driving the water, something has to drive the light bulb."
"It doesn't just happen by itself."

*Petrol is used in a car engine / A person uses up food running a race:*
"You gotta put energy in and then take it out - use it, burn it up, in other words."
"That is stored ... "
"That is driving that."
" ... but then it's released.  It's stored then it's released, but then the person's running."

## Activity C1 Energy transfer

### *Aims*

- To compare different ways in which the content of the 'energy transfer' innovation may be transformed by teachers.
- To explore factors related to the content of the innovation that may influence the transformations.
- To consider these issues in the light of your own teaching experience.

### *Background*

A common way of introducing the concept of energy is through identifying 'forms of energy' and the idea that energy can be transformed from one form to another. The National Curriculum, however, talks only of teaching about 'energy transfers'. What views do teachers have about the scientific ideas in the two approaches? How 'new' is the 'new approach' and how well does it fit into what they are already doing? How have they adapted the approach? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity C1  Energy transfer (cont.)

### *Stories*

**A** I have now adopted the approach taken in the National Curriculum, and all of my teaching about energy is in terms of energy transfer. I teach pupils that there are six different kinds of energy, and in an energy change, energy is transferred from one kind to another. I think that this is a helpful way of looking at things. I think it is probably better to say that chemical energy is *transferred* into heat energy than to say that chemical energy is *transformed* into heat energy.

**B** I think that talking about transfers of energy is probably more scientifically correct than talking about forms of energy, but in fact I continue to use the 'forms of energy' approach. I don't actually use the terms 'forms of energy' and 'energy transformation', but I do teach pupils about 'heat energy' and 'chemical energy' and so on, and get them to work out energy change diagrams.

**C** I think that from the scientific point of view, the 'transfer' approach has problems. It encourages thinking about energy as a sort of substance, and I don't think that this is helpful. Also, I think that the idea that electrical currents can carry energy does not sound right. It suggests a sense of *purpose*, which is misleading. Forms of energy make sense as a way of introducing energy because later on we use different formulae for different forms of energy. Also it is easier to talk about forms of energy when we talk about energy being degraded.

**D** I think that both ways of talking are valid. If you are teaching about conduction, for example, and how heat travels from hot to cold, then energy transfer is a good way of explaining it. Energy transfer is also a good way of thinking about how energy can become less useful as it spreads out and becomes dissipated in the surroundings. However, if you are talking about a chemical change or a change of state, then forms of energy are easier to use in an explanation. So in the classroom I just use what seems to be most appropriate at the time.

**E** I think that there are problems with both of the approaches. I don't think that forms of energy are helpful, because different books and different people use different systems. In one book, you might read just about 'chemical energy' whereas in another they might talk about different kinds of chemical energy like food energy and fuel energy. This is very confusing. But I don't think that thinking of energy as 'just one kind of stuff' helps either because I think it is important to distinguish two fundamental kinds of energy – kinetic and potential – because fundamentally everything can be seen in these terms. However, I find it difficult to see how to use these ideas in my teaching.

**Section C Transformations: content** **Page 1 of 2**

## Activity C2 Energy and change

### *Aims*

- To compare different ways in which the content of the ‘Energy and Change’ innovation may be transformed by teachers.
- To explore factors related to the content of the innovation which may influence the transformations.
- To consider these issues in the light of your own teaching experience.

### *Background*

The project ‘Energy and Change’ attempts to innovate in a number of different ways. Its most fundamental aim is to introduce ideas to explain ‘why things change’. These ideas are related to the Second Law of Thermodynamics. In order to support this it introduces a novel abstract picture language to help pupils to understand these ideas, as well as ways of talking about them using terms that are not part of existing school science. How do teachers see these ideas and how do they relate to existing work? How can these activities be integrated into schemes of work? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity C2 Energy and change (cont.)

### *Stories*

**A** I don't think that there are really any new scientific ideas in the *Energy and Change* materials. It is a very different approach, of course, with all of the abstract pictures and new terms, like 'things that just happen' and 'chemical springs'. But all of the ideas about energy are basically the same as the ones we're already doing, so I don't see that it would be too difficult to work in the activities into the schemes of work we already have.

**B** The 'Second Law' ideas in these materials are new, though I think that the science is not presented rigorously enough. Some of the explanations use language which is too informal and do not use proper scientific terms. The abstract pictures seem to be rather arbitrary, and don't relate to conventional science.

**C** The ideas in the materials are very different from what we are already teaching, so I think it would be very difficult to incorporate the activities into the topics in our schemes of work. However, I think that the ideas they develop are very useful for pupils to have when it comes to understanding some of our existing topics. So, a good approach would be create a new topic that would just contain *Energy and Change* materials.

**D** I am quite enthusiastic about introducing this kind of 'Second Law' thinking into my teaching. I think that it would be possible to modify our existing schemes of work to integrate these ideas. I don't think, however, that it would be possible to use the *Energy and Change* activities as they stand. I think that what I would do would be to adapt some of the ideas to fit in with our existing approach, and to include some abstract pictures in our current worksheets. I think that the pictures work well in illustrating the different ways in which energy can change from one form to another.

**E** I think that it should be quite easy to slot the activities into what we do already. There are lots of new ideas here, as well as new approaches, and I think that it will add variety to out schemes of work. However, what is going to be difficult, I think, is to use these ideas in the lessons that outside of the *Energy and Change* activities. In scientific terms, I think the ideas are wide-reaching, but in practice I think it is difficult to relate them to the content of school science.

# Activity D1 Energy transfer

## *Aims*

- To explore factors related to beliefs about learning that may influence teachers' transformations of the 'energy transfer' innovation.
- To consider these issues in the light of your own beliefs and teaching experience.

## *Background*

When teachers were asked how they approached teaching about energy, and their reasons for it, they had strong views about how pupils could be supported in their learning. This is not surprising, since, pupil learning is after all their major concern, and they have built up a great deal of expertise in this area. Beliefs about how pupils learn clearly influence how innovations are taken up. Is the 'transformation' or 'transfer' approach to energy easier for pupils? Which gives them a better understanding of the science? Does it depend on their age or what they are studying? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

## *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity D1  Energy transfer (cont.)

### *Stories*

**A**  I think that pupils would find it difficult to understand the idea that energy is always the same kind of stuff, and that is just moves from one place to another. This is a very abstract idea, and this is not the way it looks to them at all. When something is hot this seems to be a very different kind of energy than when something is moving. I think that this energy transfer approach in the National Curriculum is not really appropriate at school level.

**B**  I think that ‘energy transfer’ is an easier term for young pupils to understand than ‘energy transformation’. Pupils find it easier to say that one form of energy is transferred into another than to say that it is transformed – they are more familiar with the word. So I guess that is why the people who wrote the National Curriculum chose to use this word.

**C**  It depends really on the age of the pupil and what they are studying. For younger pupils, I think that identifying different ‘forms of energy’ is probably the best way of introducing the concept to them. It gives them some ‘concrete’ ideas that they can grasp, so that they can learn more abstract ideas later. Energy transfers make more sense with older pupils, when they are looking at waves, for example, or at macroscopic changes involving particles.

## Activity D2  Energy and change

### *Aims*

- To explore factors related to beliefs about learning that may influence teachers’ transformations of the ‘Energy and Change’ innovation.
- To consider these issues in the light of your own beliefs and teaching experience.

### *Background*

Beliefs about how pupils learn clearly influence how innovations are taken up. The abstract pictures in the ‘Energy and Change’ materials are designed to help pupils to generalise about situations and to see differences and similarities between them. This is an important aspect of scientific thinking. The activities that use these pictures are intended to focus pupils’ attention on important features of situations and to stimulate discussion amongst them. How well do teachers think that pupils will understand these pictures? Do they think that the activities are useful learning tools? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1.  It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2.  Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3.  After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity D2 Energy and change (cont.)

### *Stories*

**A** I think that the pictures are too abstract, and pupils will find them very difficult to understand. What they need are lots of concrete activities. I think that pupils will learn more about energy by experiencing it first-hand through practical work, than by theory work.

**B** The activities are different and new, so it's not easy to say how pupils would react to them, or to the abstract pictures. Even though I've been teaching a long time I'm often surprised how pupils manage things that I had expected to be difficult (and struggle with things I thought would be trivial). I think I would need to try the ideas, and experiment with different approaches, before I made my mind up.

**C** I think that the abstract pictures could be particularly helpful for pupils of lower achievement and for those who find language difficult. Using these pictures allows them to do activities that encourage them to think and talk about scientific ideas without having to do a lot of reading or writing. They can use more informal and commonsense ways of taking about the ideas.

**D** I think that pupils would find this work challenging, but I am not too worried about that. I don't think that they should always do work which has clear right or wrong answers, and it does not matter if they do find some parts of the activities difficult. This is a useful way of clarifying ideas.

## Activity E1 Energy transfer

### *Aims*

- To explore factors related to personal values that may influence teachers' transformations of the 'energy transfer' innovation.
- To consider these issues in the light of your own values and teaching experience.

### *Background*

Our actions are guided by what we see as important and what we value. Often, we may not make our values explicit, but they have an effect all the same. When teachers described their work on teaching energy, they referred to personal values about what should be in the curriculum and how it should be taught in the classroom. What kind of science should pupils be taught? What is the nature of scientific knowledge? What kind of science is defined by the National Curriculum? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity E1 Energy transfer (cont.)

### *Stories*

**A** It is very important that what we teach to children is scientifically accurate and correct. We should not be teaching anything to pupils which we later have to tell them is wrong. Since this energy transfer approach is correct and forms of energy are not, then I'm certainly committed to doing it this way. I don't see a problem in making sure the department implements it in every topic immediately.

**B** I don't think that there is just one way of thinking about science, and I don't think that there is a unique way of developing scientific concepts. I can't see anything wrong in talking about a concept in one way with younger pupils and then later on saying that there is another more sophisticated way of looking at things. That's not to say that the earlier version was wrong, just different.

**C** We are legally obliged to teach what is in the National Curriculum, and so I can't see that there is really any debate about it. I'm not an expert on energy, and I don't really know which is the best approach. But lots of experts have had an input into the National Curriculum, and it quite clearly states that we have to teach about energy transfers, so I guess that is what we have to do.

**D** I think that as professionals we have to exercise some judgement over how we interpret the National Curriculum. We need to teach in ways which we think are best for our pupils. When I am teaching about energy I pay much more attention to what is in the SATs tests than what is in the National Curriculum. At the end of the day, it is how they perform on the tests which is what is important for the pupils.

**Section E Transformations: values** **Page 1 of 2**

## Activity E2 Energy and change

### *Aims*

- To explore factors related to personal values that may influence teachers' transformations of the 'Energy and Change' innovation.
- To consider these issues in the light of your own values and teaching experience.

### *Background*

Our actions are guided by what we see as important and what we value. Activity E1 looked at the consequences of this in relation to the teaching of energy transfers, and the stories in that activity are equally relevant in relation to 'Energy and Change'. The stories in this activity address further questions. How important is it that pupils should be able to abstract fundamental similarities and differences between changes? Is it necessary to include 'Second Law' ideas in the curriculum? What purpose do they serve?

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

**Section E Transformations: values** **Page 2 of 2**

## Activity E2 Energy and change (cont.)

### *Stories*

**A** Science teaching should aim to make pupils ‘scientifically literate’, so they can understand things like the environment, the impact of technology, and so on. There are a lot of scientific ideas which are not covered in the current curriculum. I think it is important for pupils to learn about ‘Second Law’ ideas in order for them to understand the world energy crisis, so I would like to see this included in the curriculum.

**B** There is too much emphasis on practical work in school science, so I am attracted to these materials which emphasise the importance of abstract thinking. Practical work is not sufficiently intellectually demanding. I think that science teaching should focus more on theoretical ideas, which challenge pupils to think and which will train their minds.

**C** In the lessons that I teach, I try to make links between different parts of the same topic and between topics. In practice though, I think that school science is too ‘bitty’. I think that we ought to be teaching about these big scientific ideas, like the Second Law of Thermodynamics. We can use these ideas to provide a structure for the science curriculum, and give a sense of coherence and progression.

**Section F Transformations: contexts, customs and constraints** **Page 1 of 2**

## Activity F1 Energy transfer

### *Aims*

- To explore factors related to contexts, customs and constraints that may influence teachers' transformations of the 'energy transfer' innovation.
- To consider these issues in the light of your own teaching experience.

### *Background*

Even when teachers were committed to the innovation, it might not always have been easy to implement it because of the particular contexts within which they worked. There are customary practices that may be difficult to change, and there are other constraints that may hinder changes. How are teachers affected by factors related to science department of the school. How are they affected by factors outside the school, including the national context? What are the constraints of the individuals themselves? The following stories address these questions.

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

### *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity F1 Energy transfer (cont.)

### *Stories*

**A** I'm not sure how we were expected to implement this change in the teaching of energy. When the National Curriculum first came out, I don't think that we really noticed what was being said, and we certainly didn't understand it. There wasn't any supporting documentation or any training to help in a new approach. Even if there was, I'm not sure we would have had time to have taken advantage of it anyway.

**B** I have read a lot about how to teach about energy. I am keen to implement this new 'energy transfer' approach, but this is not the way that it is done in my school's schemes of work. I am new to the school, and so I don't feel very comfortable about departing from them. I don't think it would be very easy to persuade the department to change the schemes of work either.

**C** The 'forms of energy' approach was the way that I was taught about it when I was at school, and I have taught it this way myself now for several years. I now feel quite confident about teaching energy which I certainly didn't when I started. I'm always quite keen to try out new ideas, but I'm reluctant to change my teaching about energy as it seems such a difficult topic.

**D** Basically, I think that we are very influenced in our department by the textbooks that we have. When it comes to teaching about energy, they all seem to have their own particular approach, so this makes it quite difficult to choose what to use from different books without confusing the pupils. All the ones we use seem to talk about forms of energy, so if we didn't teach pupils about that then they wouldn't understand them. We also have to think about what is in the exam board's syllabus and in the exams.

# Activity F2 Energy and change

## *Aims*

- To explore factors related to contexts, customs and constraints that may influence teachers' transformations of the 'Energy and Change' innovation.
- To consider these issues in the light of your own teaching experience.

## *Background*

Even when teachers were committed to the innovation, it might not always have been easy to implement it because of the particular contexts within which they worked. Activity F1 looked at the consequences of this in relation to the teaching of energy transfers, and the stories in that activity are equally relevant in relation to 'Energy and Change'. The stories in this activity address further questions. Will learning about these novel ideas be of benefit to pupils? How will it affect teachers' motivation and commitment?

*[N.B. These stories are based on research into the work of teachers implementing this innovation. Though they are not based on particular individuals, they do focus on issues that were identified in the research.]*

## *What to do*

1. It is best to do this activity in a group of two or three. Before you start discussion, however, work individually and read through each of the stories on page 2. For each story, decide whether you are:

- broadly sympathetic to the position outlined in the story (S)
- broadly unsympathetic to the position outlined in the story (U)
- neither (N)

Write the appropriate letter next to each story.

2. Discuss each story in turn within the group. It may be useful to think about the following:

- What is the key idea of the story?
- Are there points that the teacher makes that we all agree with?
- Are there points that the teacher makes that we all disagree with? If so, is this because we disagree in principle or because we think the teacher has said something factually incorrect? Or because they say something which may apply in their own situation but not in yours?
- What are the issues where we do not reach a consensus? What are the reasons for this?

3. After discussion, work individually again and look back over all of the stories. Pick out a few key sentences, which you agree with and think address the most important ideas for you. Underline them. Pick out a few sentences that you disagree with strongly. Underline them in a different colour or style. (Make a note of what the colours/styles mean so that you can work it out later.) You will be returning to these sheets in a later session.

## Activity F2  Energy and change (cont.)

### *Stories*

**A**  I can see that the materials put an emphasis on developing pupils' understanding of a wide variety of different kinds of change. In this respect, they have the potential for being useful across a whole range of topics. I'm probably being too cynical, but my concern is that increased understanding of fundamental ideas is not what tests and exams are actually testing.

**B**  One thing that these materials have done is to help me develop my own understanding of some scientific ideas that I have not really thought about for a long time. I suppose this should mean that I am able to teach these things better, but I'm not sure it always works out that way, as teaching concepts to pupils is a very different thing. Sometimes knowing more just makes me realise how badly I've been teaching a topic, without helping me to do it better.

**C**  I think that it will be necessary to have a departmental approach to the activities. Unless they are integrated into the schemes of work so that everyone is required to do them, then I think only the more committed teachers will do them. But I think it is the committed ones that will have to try them out first, so it really means that the activities will need to be incorporated a bit at a time, rather than by a radical overhaul.

## Activity G1 Using the new ideas

### *Aims*

- To plan, teach and evaluate a lesson drawing on the new ideas introduced in these workshop materials.
- To prepare for the next workshop session by reading case-study material.

### *Background*

Before the next session, you should try to implement in the classroom some of the ideas that you have learned in the earlier activities. In planning and evaluating your lesson, try to think about the 'stories of transformations' and how these relate to your own practice. You will be discussing this at the next session. You will also be looking in more detail at case-study material about teachers involved in the research on transformations of innovation, and it will be useful to read this material before the next session.

### *What to do*

1. Using ideas that you have learned about in Section B, plan a lesson about energy that fits into your existing scheme of work. Make some notes that justify the choices you have made. Think about the 'stories of transformation' that you looked at in Section C, D, E and F, and how your choices have been influences by factors such as the subject content, your beliefs about learning, your values, and by customary practices and constraints.

You might like to look at the scheme of work for key stage 3 that has been produced by the Qualifications and Curriculum Authority for some ideas about teaching energy. Some extracts from this publication are given on pages 2 and 3. For each of Years 7, 8 and 9, two extracts are given. The full publication is available at:

http://www.standards.dfee.gov.uk/schemes

2. After teaching the lesson, make some notes about your evaluation of the lesson. In the next session, you will discuss your lesson and your evaluation with the other members of the group. You should include the following criteria in your evaluation:

- How well do you think the scientific ideas fitted in with the other work about energy that pupils study?
- Did the pupils appear to understand the ideas?
- What criteria did you use to assess whether pupils understood the ideas?
- Do you think that these ideas are important for pupils to learn?
- Do you think that the work helped pupils in preparation for test and examinations?
- Did you find that you needed to adopt new classroom strategies to implement the approach?
- Did you feel uncertain about your own understanding of the scientific ideas?
- Were you limited in what you could do because of constraints in resources?

3. In preparation for the next session, it will be useful to read one of the documents that contain case study material about teachers implementing the innovations. One of these documents (Activity Resource 1) relates to the 'Energy Transfer' innovation, and the other (Activity Resource 2) relates to the 'Energy and Change' innovation.

**Section G Planning** **Page 2 of 3**

## Activity G1 Using the new ideas (cont.)

| **Learning objectives** Pupils should learn: | **Possible teaching activities** | **Learning outcomes** Pupils: |
|---|---|---|
| **Unit 7I Energy resources** *Extract from 'Why are fuels useful?'* | | |
| • that fuels are substances which burn to release energy | • Review pupils' understanding of the word 'fuel'.<br>• Ask pupils *What fuels can you name and what do we use them for?* This leads to a general statement that when fuels burn they make things happen. Introduce the definition of 'energy' as what burning fuels release to make things happen. | • identify some common fuels<br>• identify fuels as sources of light, heat and movement, all of which can be called energy |
| **Unit 7I Energy resources** *Extract from 'How do living things use energy?'* | | |
| • that we (and all living things) need energy for every activity<br>• that food is the energy source of animals<br>• that energy is measured in joules | • Review with pupils their ideas about food as the energy resource for plants and animals. This will have been covered at key stage 2, although the word 'energy' will not have been used. Link this use of the word 'energy' to its use in situations they have just studied.<br>• Use pupils' knowledge of 'calorie counts' for slimming or body-building to introduce the idea of measuring energy input. Introduce the joule as the unit of energy. Demonstrate that it is quite a small unit, *eg lifting an apple by 1 metre takes about 1 joule of energy.* Look at the energy ratings of food, *eg a chocolate bar.* Ask pupils to consider the question *If you ate the chocolate bar how high would you have to lift the apple before all the energy is used up?* Tell them about the famous physicist John Tyndall, who worked out that the energy he needed to climb the Matterhorn was contained in a ham sandwich, so that was all the food he took with him. | • know that living creatures need energy to live<br>• identify the energy contents of a sample of food, *eg from a label* |
| **Unit 8I Heating and cooling** *Extract from 'How do things get hotter or colder?'* | | |
| • to recognise heat as energy<br>• to use a model which associates energy flow with temperature change<br>• to make predictions and compare these with observations<br>• that heat flows as a result of temperature differences | • Remind pupils of year 7 work on the heating effect of burning fuels, where energy was released to cause temperature rise. Discuss the energy flow associated with the cooling of boiling water and the warming of ice in the classroom.<br>• Elicit pupils' ideas about how heat and temperature are linked and establish that they are not the same thing. Ask pupils to predict and observe how the temperatures change when they, *eg mix volumes of hot and cold water, boil different quantities of water with the same heater.*<br>• Through questioning, help pupils explain why their predictions matched or did not match the observations they made. | • describe the flow of heat (energy) in an everyday situation of temperature change, *eg the cooling of hot food*<br>• relate a flow of heat to change in temperature<br>• relate a difference in temperature to a flow of heat<br>• give reasons for their predictions and for any differences between the predictions and observations |

Extracts taken from 'Science: A scheme of work for key stage 3' (2000) (Qualifications and Curriculum Authority)

**Section G Planning** **Page 3 of 3**

## Activity G1 Using the new ideas (cont.)

| **Learning objectives** Pupils should learn: | **Possible teaching activities** | **Learning outcomes** Pupils: |
|---|---|---|
| **Unit 8I Heating and cooling** *Extract from 'How can we reduce energy waste?'* | | |
| • that insulation can reduce unwanted energy transfer | • Review pupils' key stage 2 work on insulators, where they may have investigated keeping cups of liquid warm or preventing ice cubes melting.<br>• Recap year 7 work on the need to conserve energy resources. Ask groups to discuss the ways used to prevent energy escaping from homes, *eg loft insulation, heavy curtains, cavity-wall insulation.*<br>• Use models to explain how these methods work, *eg double glazing, draught* excluders. | • describe and explain how a house can be fitted out to reduce heat loss |
| **Unit 9I Energy and electricity** *Extract from 'How is energy involved in doing useful things?'* | | |
| • that useful changes usually involve energy transfers and transformations<br>• that the terms 'kinetic', 'potential', 'radiation' and 'chemical' are useful when describing energy | • Remind pupils of their experience of energy transfers and transformations in years 7 and 8 with demonstrations of 'useful changes', *eg working a model steam engine, a spring-driven clock, eating food.* Help pupils associate the presence of energy with the different situations in the demonstrations, *eg steam-engine fuel, flame, hot water, movement*, and to use the terms 'kinetic', 'potential', 'chemical energy', 'heat', 'light' and 'sound' as ways of describing energy in such situations.<br>• Ask pupils to explore a circus of toys and devices that work by transferring and/or transforming energy. Ask pupils to identify the source of energy and the use to which it is put. Include a range of electrical toys and devices. | • recognise that energy is routinely converted from one form to another in order to be useful<br>• categorise devices on the basis of type of energy input or output<br>• explain why electricity is used widely as a source of energy<br>• describe energy transfers in everyday changes |
| **Unit 9I Energy and electricity** *Extract from 'How can we reduce the waste of energy?'* | | |
| • that when energy is transferred the total amount of energy remains constant<br>• to use flow diagrams to show qualitatively how energy is transferred/transformed in devices | • Introduce the principle of the conservation of energy, using a range of examples to make the distinction between energy that is useful and energy that is dissipated and not useful. Ask pupils to draw flow diagrams, *eg Sankey-type,* to show energy transfers in everyday situations, *eg home heating, transport, use of insulation.* | • use flow diagrams as a simple means of energy accounting |

Extracts taken from 'Science: A scheme of work for key stage 3' (2000) (Qualifications and Curriculum Authority)

## Science Teacher Training in an Information Society (STTIS)

## Teacher Workshop (UK)

# Teaching about energy

## Activities for Workshop 2 (Sections H – K)

## Teachers' Workshop 2

### *Introduction*

This second workshop is designed to help you to build on the experience of the trial lesson about energy in order to plan more extended sequences of lessons within the schemes of work. To support you in developing this work, in this workshop you will:

- review and evaluate the trial lesson;
- learn more about research work through examples of case studies, relating these and your own experiences to the general findings of the research;
- consider again the factors that affect your planning choices and review the appropriateness of teaching sequences on energy.

For more details about the rationale behind the workshop, look at the section on Aims. If you want to see a list of all the activities in the workshop, go to the Activities section, from where you can also download Word files of the activities.

*Aims*

The main aims of the activities are:

Section H: Evaluation

- To report back to the group about your experiences in teaching some aspect of energy.
- To evaluate these experiences taking account of the factors that affect the transformation of curriculum innovation.

Section J: Relating to research case studies

- To consider some examples of case studies and to relate these to the general findings of the research on teachers' transformations.
- To review your own experience and compare it with the case study material.

Section K: Innovation and transformation

- To reconsider the 'stories' about transformations in the light of your further experiences.
- To build on work already undertaken in planning a single lesson to consider how to extend the approach to sequences of lessons.

*Activities*

This is a list of all the activities in the second workshop. If you want to browse through the activities, then you can view these documents directly as web pages. If you wish to do the activities, in most cases you will find it easier to download the documents as Word files.

Section H: Evaluation
  Activity H1: Evaluating the new ideas in the classroom

Section J: Relating to research case studies
  Activity J1: Energy transfer: research on teachers' transformations
  Activity J2: Energy and Change: research on teachers' transformations

Section K: Innovation and transformation
  Activity K1: Review and further planning

## *Section H: Evaluation*

In the previous workshop you were asked to plan and teach a lesson about energy that fitted into your existing scheme of work, drawing on the new curriculum ideas that that had been introduced. In this section, you will report back to the group about your experiences. As a group you will discuss these experiences relating them to the factors that affect the transformation of curriculum innovation.

The activity in this section is:

- Activity H1: Evaluating the new ideas in the classroom

## *Section J: Relating to research case studies*

The 'stories' that you looked at in the first workshop, about the ways in which teachers approach and implement curriculum innovation, were simplified accounts drawn from real case studies. They were simplified because they viewed the factors that affected teachers' transformations in isolation. Reality is more complex, since transformations are brought about not by single factors, but by factors that overlap and interact with each other. In this section, you will look at examples of case studies from the research that attempt to capture some of that complexity. You will relate the case studies and your own experience to the general findings of the research on teachers' transformations.

The activities in this section are:

- Activity J1: Energy transfer: research on teachers' transformations
- Activity J2: Energy and Change: research on teachers' transformations

## *Section K: Innovation and transformation*

In this final session, the focus is on further planning. You will consider again the 'stories' about transformations, and think about whether any of your ideas have changed. In the planning of the first lesson, you were asked to consider how ideas affected the choices that you made. Having taught and evaluated the lesson, it is important to revisit these issues, before building on this work to consider how the new approaches can be incorporated into the curriculum as a whole, and to think about sequences of lessons.

The activity in this section is:

- Activity K1: Review and further planning

**Section H Evaluation** **Page 1 of 1**

## Activity H1 Evaluating the new ideas in the classroom

### *Aims*

- To report back to the group about your experiences in teaching some aspect of energy.
- To evaluate these experiences taking account of the factors that affect the transformation of curriculum innovation.

### *Background*

In the previous workshop you were asked to plan and teach a lesson about energy that fitted into your existing scheme of work, drawing on the new curriculum ideas that that had been introduced. In planning and evaluating the lesson, it was suggested that you think about the factors that affected the choices that you made. In the workshop, you also explored factors affecting the transformations of curriculum innovation through ‘stories’ that drew on the case studies of teachers who took part in the research. These factors were categorised as related to:

- Content
- Beliefs about learning
- Values
- Contexts, customs, constraints

The factors are reflected in the evaluation criteria that were suggested in the previous activity.

### *What to do*

1. Briefly describe to the others in the group the nature of the lesson that you planned and taught, and the key points of the evaluation.

2. After everybody in the group has reported back, then consider each of the evaluation criteria below:

- How well do you think the scientific ideas fitted in with the other work about energy that pupils study?
- Did the pupils appear to understand the ideas?
- What criteria did you use to assess whether pupils understood the ideas?
- Do you think that these ideas are important for pupils to learn?
- Do you think that the work helped pupils in preparation for test and examinations?
- Did you find that you needed to adopt new classroom strategies to implement the approach?
- Did you feel uncertain about your own understanding of the scientific ideas?
- Were you limited in what you could do because of constraints in resources?

On which of these points is there a measure of agreement? On which points do you disagree? Why?

## Activity J1 Energy transfer: research on teachers' transformations

### *Aims*

- To consider some examples of case studies related to 'Energy transfer'.
- To relate the case studies to the general findings of the research on teachers' transformations.
- To review your own experience and compare it with the case study material.

### *Background*

The 'stories' that you looked at in the first workshop, about the ways in which teachers approach and implement curriculum innovation, were simplified accounts drawn from real case studies. They were simplified because they viewed the factors that affected teachers' transformations in isolation. Reality is more complex, since transformations are brought about not by single factors, but by factors that overlap and interact with each other. The case studies presented here attempt to capture some of that complexity. They are about two student teachers, Farida and Man Pong, who are teaching lessons about energy as part of their school experience.

### *What to do*

1. Read the case studies in the document 'Activity Resource 1' ('Energy transfer': case studies).

2. Consider the following questions in relation to these case studies.

   - To what extent do you think that these teachers have distinguished between the concepts of 'energy transformation' and 'energy transfer'?
   - Which concept do they think is easier? How do they justify this?
   - Was there consistency between their intentions, their explanations and the resources that they used?
   - If you had just observed these student teachers' lessons, what discussion might you have with them about the approach they used to teaching about energy?

3. Read the document 'Activity Resource 3' (Transformation of curriculum innovation: dimensions of analysis), which gives a summary of some findings of the research into teachers' transformations. These findings are expressed in general terms, without examples from particular curriculum innovations. Can you relate any of the aspects identified in this summary to the case studies or to your own experience?

**Section J Relating to research case studies** **Page 1 of 1**

## Activity J2 Energy and Change: research on teachers' transformations

### *Aims*

- To consider an example of a case study related to the 'Energy and Change' materials.
- To relate the case study to the general findings of the research on teachers' transformations.
- To review your own experience and compare it with the case study material.

### *Background*

The 'stories' that you looked at in the first workshop, about the ways in which teachers approach and implement curriculum innovation, were simplified accounts drawn from real case studies. They were simplified because they viewed the factors that affected teachers' transformations in isolation. Reality is more complex, since transformations are brought about not by single factors, but by factors that overlap and interact with each other. The case study presented here attempts to capture some of that complexity. It is about an experienced science teacher, Ivan, who is attempting the difficult task of integrating the 'Energy and Change' materials into the school's existing schemes of work.

### *What to do*

1. Read the case study in the document 'Activity Resource 2' ('Energy and Change': case study).

2. Consider the following questions in relation to these case studies.

- What benefits does Ivan believe the new approach will bring to pupils' understanding of energy?
- How is he going about ensuring that the approach will be systematically used by other teachers in the department and how is he supporting them?
- To what extent has Ivan adapted the scientific ideas of the Energy and Change materials to fit into the existing schemes of work?
- Do you think that this approach would work in your own department? What other approaches might be appropriate in your own context?

3. Read the document 'Activity Resource 3' (Transformation of curriculum innovation: dimensions of analysis), which gives a summary of some findings of the research into teachers' transformations. These findings are expressed in general terms, without examples from particular curriculum innovations. Can you relate any of the aspects identified in this summary to the case study or to your own experience?

## Activity K1 Review and further planning

### *Aims*

- To reconsider the 'stories' about transformations in the light of your further experiences.
- To build on work already undertaken in planning a single lesson to consider how to extend the approach to sequences of lessons.

### *Background*

Now you have planned and taught a single lesson, this final activity is concerned with how the new approaches can be incorporated into the curriculum as a whole, and to think about sequences of lessons. In the first workshop you considered some stories about teachers' transformations of innovations. For each of the areas, you identified a few key sentences that you thought addressed the most important ideas for you. In the planning of the first lesson, you were asked to consider how these factors affected the choices that you made. Having taught and evaluated the lesson, it will be helpful to look again at these key ideas, and to think about whether any of your ideas have changed. Many no doubt will have remained the same, as many of our ideas and beliefs are very stable and fundamental to the way we see ourselves as individuals. Some ideas though may change in the light of experience. For example, we are often surprised that tasks that seem difficult are accomplished easily when we try them with pupils, and what we think of as easy tasks turn out to be more difficult than we thought.

### *What to do*

1. Look back to the activities in sections C, D, E and F, and consider the key sentences that you identified. Do you still agree with each of these points? Are there other ideas from these stories that you now think are more important? If you have changed your ideas, what caused you to do so?

2. Using ideas that you have learned about in Section B, plan a sequence of lessons about energy that fits into your existing scheme of work. As in planning the single lesson, make some notes that justify the choices you have made. Think about how your choices have been influences by factors such as the subject content, your beliefs about learning, your values, and by customary practices and constraints.

You might like to look at the scheme of work for key stage 3 that has been produced by the Qualifications and Curriculum Authority, and consider the appropriateness of this suggested sequence in developing the energy concept. An outline of the key ideas to be introduced in each topic is given on page 2. The full publication is available at:

http://www.standards.dfee.gov.uk/schemes

The unit in Y7 (7I Energy resources) introduces the concept of energy in the context of fossil fuels and of energy resources for living things. The Y8 unit (8I Heating and cooling) is concerned with heat and temperature, mechanisms of heat transfer, and changes of state. In Y9, the unit (9I Energy and electricity) explores a range of useful energy changes and deals with energy conservation and dissipation. The unit uses ideas of both energy transfer (from one place to another) and energy transformation (from one kind to another).

## Activity K1  Review and further planning (cont.)

### *Unit 7I Energy resources*

In this unit pupils:

- are introduced to the concept of energy in the context of fuels as convenient and therefore valuable sources
- consider the nature and origin of fossil fuels and renewable sources of energy and how their use has implications for the environment
- consolidate and extend their ideas about energy resources for living things: food for people and sunlight for plants
- link the energy resources to the role of the Sun as the ultimate source of most of the Earth's energy resources

### *Unit 7J Electrical circuits*

In this unit pupils:

- consolidate and extend their ideas about circuits
- use concepts of electric current and energy transfer to explain the working of circuits
- explain patterns in the measurements of current and voltage
- use the concept of resistance qualitatively
- build circuits in which current flow is usefully controlled
- consider the hazards of electricity for humans

### *Unit 8I Heating and cooling*

In this unit pupils:

- recognise the need for a temperature scale
- learn to distinguish between heat (as energy) and temperature
- learn about mechanisms of heat transfer: conduction, convection and radiation, and apply this to familiar contexts
- learn about expansion and change of state in solids, liquids and gases
- use the particle model to explain conduction, convection and change of state

### *Unit 9I Energy and electricity*

In this unit pupils:

- explore a range of useful energy transfers and transformations
- discuss the use of electricity as a convenient way to transfer energy to do useful things
- associate the concept of voltage with the transfer of energy in a circuit
- investigate the voltage of cells
- study how electricity is generated, with reference to environmental impacts
- use the principle of conservation of energy to identify ways in which energy is dissipated during transfers

Extracts taken from 'Science: A scheme of work for key stage 3' (2000) (Qualifications and Curriculum Authority)

## Science Teacher Training in an Information Society (STTIS)

## Teacher Workshop (UK)

# Teaching about energy

## Activity Resources

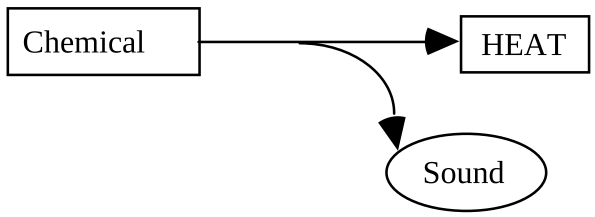
***Activity Resource 1***

# ‘Energy transfer’: case studies

Farida and Man Pong are two students training to become science teachers and doing their teaching practice in state schools. Each of them taught a lesson about energy were observed teaching about energy and were interviewed .

## *Farida*

Farida’s lesson was an introductory one on energy with a Y7 class (11-12 year-old pupils). The objectives she had set for this lesson were to get all pupils to know that energy is needed to make something happen and to learn the six main types of energy. She had also hoped that most pupils would understand that energy is stored and can be transferred, and moreover that some of them would understand that energy is conserved and never disappears. In the actual lesson, consistent with these goals, Farida called the idea that *“we need energy to do everything”* the key point of the lesson and then established that chemical, light, electrical, heat, movement and sound are the six main types of energy. She then went on to talk about energy transfers and introduced the energy transfer diagrams; she drew the following energy transfer diagram for the change of ‘rubbing your hands’.




She said about it:

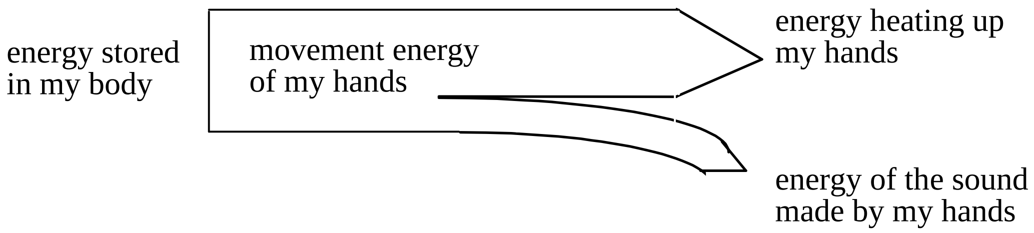
> *“We don’t rub our hands to produce sound, but also sound energy is produced. Chemical energy is* transferred *to heat energy. ‘Transferred’ is an important word to learn and remember. Energy can be transferred from one place to another or from one form to another.”*

Later in the lesson Farida added in the above diagram ‘movement’ as one of the energy forms being ‘produced’ during the change.

The pupils were then shown several gadgets and asked to work in groups of five to draw an energy transfer diagram for one of them. The task proved quite a struggle for most pupils; to help them Farida prompted them with questions such as ‘what type of energy does it use’; ‘what are the transfers of energy’; ‘what is the final energy’.

Finally, two worksheets were given to the pupils for homework. One asked them to tick the types of energy they thought that are involved in each of six situations, and the other to fill in already drawn energy transfer diagrams (of the sort they had seen in the lesson) with the appropriate types of energy for a list of ‘energy changers’. These are defined in the worksheet as machines or other equipment designed to change (or transfer) one type of energy into another.

The energy transfer diagrams in the worksheet and drawn by Farida make use of two conventions to represent the ‘produced’ types of energy; the ‘less useful’ types of energy appear inside ellipses or circles and the ‘more useful’ ones inside rectangles. Although on the whole Farida followed the school’s lesson plan conscientiously, she deviated from it in some ways. As a reference for the teaching of the energy transfer diagrams the schemes of work mention another textbook in which the equivalent diagram of ‘rubbing your hands’ appears as follows:




Moreover, the school's scheme suggests that the teacher should emphasise the idea that *energy is transferred* for jobs (work) to be done; Farida changed this into *energy* is needed to get jobs done.

When interviewed, Farida correctly identified the difference between transferring energy and transforming it, and then expressed her thoughts about their use as follows:

> *"There is a difference talking about just transferring the energy and transformation cos when you're saying 'transformation' implies you change the shape and the form and everything of the energy. 'Transformation' is probably a better word, but for the younger years 'transferred' is easier to understand. So 'transformation' would probably be used, that sort of language, with the GCSE and they'd be able to understand what transformation actually means and implies as well. With the younger years it's easier to use transfers which is a simpler context - just moving rather than changing everything."*

So, 'transfer' for her is an easier word and ought to be used with younger pupils; 'transformation' better expresses what is happening, which is that energy is changing form, but as it implies something more complicated it should be used with older pupils. Consistent with this line of reasoning, Farida argued that the National Curriculum had chosen to use only the word 'transfer' because it refers to all pupils even those *"who have lower ability or maybe language problems"* and who might find easier to understand 'transfer' rather than 'transformation'.

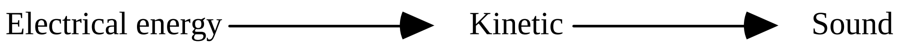
### *Man Pong*

Man Pong also had a Y7 class in the first year of secondary school. They were studying a series of five lessons on energy changes and energy transfer. The first two lessons were taught by the class's usual teacher; the third lesson, which is described here, was taught by Man Pong. In the first lesson pupils had been introduced to energy as something needed for jobs to be done, and had looked at the types of energy present in different situations. In the second lesson the idea of 'potential energy' and 'stored energy' had been introduced, with 'stored energy' being further subdivided into chemical, gravitational and elastic. Pupils had identified the types of energy associated with various examples and demonstrations, and had done a calculation on how much energy they used in a day based on vales for different activities. According to the school's scheme of work, Man Pong now had to teach about energy changes and energy transfer and show the class how to draw energy transfer diagrams.

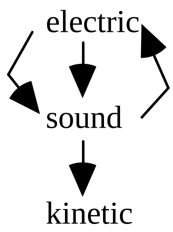
Man Pong consistently throughout the lesson talked about 'energy changes' and energy 'changing' from one form to the other. Only towards the end of the lesson did he introduce the word 'transfer'; he asked the pupils what it meant and got the answer that it meant taking something from one place to another. Man Pong agreed and offered them as concrete example that if they were naughty they might be transferred to a different school. And further employing the word in the context of the energy lesson he said:

> *"Energy can change or can move to another form; in other words 'transfer'."*

The energy flow diagrams he drew consisted of names of energy forms linked with thin single-line arrows. Man Pong used a variety of demonstrations talking about energy changes; he had also set up a circus of examples of energy transfers around the lab and asked pupils to draw energy diagrams for each example they looked at. The instructions he gave them were to identify the energies involved, to put these in order, and to think of where energy comes from and what it turns into.  Some of the contraptions on the benches such as the oscilloscope, the radio or the light sensor were complicated enough to confuse several pupils.  Things became more difficult when Man Pong attempted to talk about a series of energy changes, and drew for an electric bell the following diagram




As a result some pupils drew energy diagrams with arrows flowing out in all directions.  One pupil for example drew the following diagram for an oscilloscope:




In the interview, Man Pong seemed aware of the existence of an issue about the teaching of energy. However, he admitted to not making much sense of it:

> *"Well, erm, I think it's been said that there is a difference [between the two ways of talking about energy], like people are encouraged not to teach energy as particular forms like chemical energy, or movement energy, but rather they would like to teach people, teach pupils to understand that energy, erm, that energy is not confined to any particular form, that it is transferred, ohh, it's hard to explain.  That it is transferred quite from one form to another.  I don't know, it doesn't make sense, does it?"*

Whereas Man Pong put his finger on the cause on the confusion, because it really does not make sense to talk about energy transfer from one form to another, even in plain English, he was not able to resolve the confusion.

He associated the use of different forms of energy with macroscopic explanations of changes and thus deemed it to be appropriate for younger pupils. People, he said (including pupils and himself), feel safe with concrete definitions of concepts; only after having some experience with science do they get to understand the more abstract, complex and less accurate scientific models, such as the one of energy transfer.  His argument was consistent with his practice.

Overall, Man Pong seemed committed to the 'energy forms' idea and was more at ease talking about 'energy changes' (from one form to the other), rather than about 'energy transfers'.

*Activity Resource 2*

# ‘Energy and Change’: case study

This case study looks at a teacher, Ivan, who is introducing ideas from the ‘Energy and Change’ project into the school’s schemes of work. Examples from the schemes of work for Y7 and Y8 are given, and a description of a Y8 lesson.

Ivan is a very experienced physics teacher, ex-head of physics in his school, and a forward thinker who is in constant search for ways to enrich and advance the teaching of physics. He likes to try out new things, to see what works and what does not work; if he sees that something does not work he will change it until it does work.  Ivan, however, is also very realistic and pragmatic. Having been head of physics in his school he is aware and sensitive both about the need for pupils to achieve well in exams, and about the resistance the other teachers might show towards introducing something completely novel in their teaching. So his strategy is to make a piece-meal selection of the ‘Energy and Change’ materials, try them out in the classroom, share his experience with his colleagues and invite them to try them out themselves.

> *“...because people need to believe in these things and see that they can do a useful job for them.  But to get them to do that, they need to kind of start using them a bit and see whether they do and don’t work and why they do and don’t work.”*

Ivan is amending the schemes of work to use ideas from the Energy and Change project. He is doing this  is by adding pieces of the new material onto what already exists and then making the new part of the old by creating a framework to justify it all.  In other words, he is not simply adding a few new ideas to the existing ones, but is systematising their use by making them an essential component of an overarching approach to the teaching of energy.

## *Example from Y7 scheme of work*

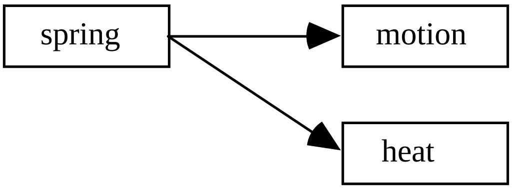
In the Year 7 scheme of work, energy is taught in a topic called ‘Fuel for toys’.  There, energy is said to be “something fuel-like [...] which enables things to happen”.  The pupils are told that it is important for them to learn to talk about the world and changes in it using energy and energy transfers because

> *“transferring energy is very important to the way we live;*
> *it is a very simple way of describing lots of complex events;*
> *we can measure how much energy is transferred;*
> *energy is conserved.”*

Talking in this way is like learning a foreign language, they are told.

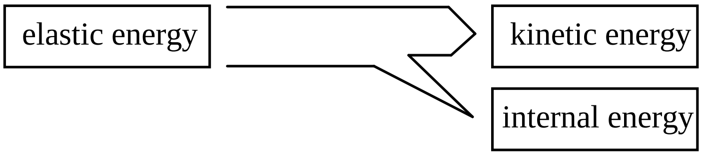
> *“First you must learn what some words mean and then try to use them.  By practice you will find out what they mean.”*

The pupils are then successively introduced to three kinds of diagrams which are said to answer different and progressively more difficult questions about the energy transfers that are involved in changes.  First come the ‘energy transfer diagrams’ which are portrayed as some “simple diagrams to help catalogue what is happening”.  To do this the pupils are taught the technical names of seven forms of energy (which are also said to have nine informal names); for a given change they are asked to figure out *what* energy is transferred to *what* and draw the corresponding diagram. According to Ivan, the aim of these diagrams is to familiarise pupils with the language of energy. For example, for a catapult which is fired, the suggested diagram and description are:

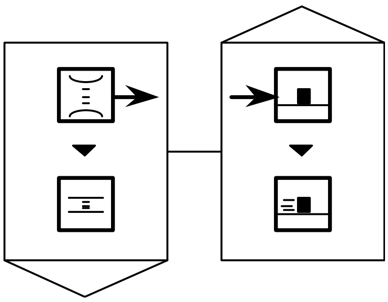



*"The spring energy is transferred to motion energy and heat energy."*

The next kind of pictures is the 'energy flow diagrams' (Sankey type diagrams). These are characterised as more complete and said to answer the questions "how much?" as well as "where to?" Pupils are asked to estimate how much energy is transferred in each route and draw the arrows accordingly. The function of these diagrams according to Ivan is to give to the pupils the notion that energy can be quantified.




Finally the third kind of diagrams are the ones developed by the 'Energy and Change' project. In the pupils' materials these are called 'energy difference diagrams' or "why" pictures. Ivan characterises these as "hard work" but they give an idea of why some changes happen and others do not. Pupils are told that "those [changes] that do just happen can drive those that will not". From changes that happen without our help "energy is made available to do something else". The catapult example is portrayed as follows:



*"We could use the energy stored in a stretched elastic band to fire something in the air."*

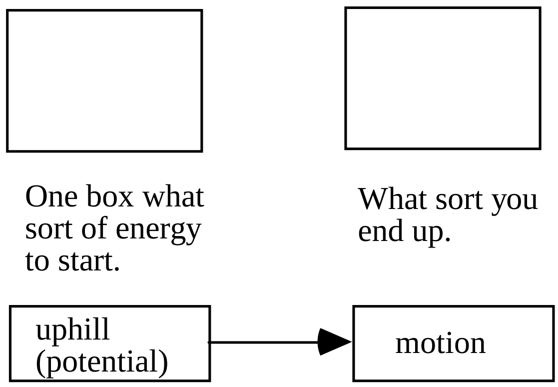
### *Example from Y8 scheme of work*

In the Year 8 scheme of work, the relevant topic is called 'Domestic Energy Transfers'. The existing topic dealt with processes of conduction, convection and radiation as "ways in which thermal energy can be transferred from one place to another". It looked at the measurement of energy in changes involving electricity and gas as fuels, and included an investigation by pupils on controlling the temperature of a house.

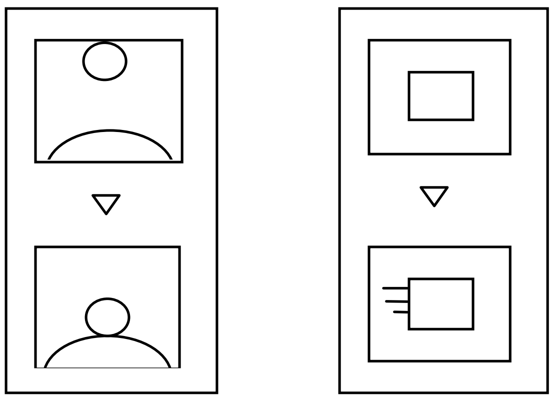
Ivan's amendments to this program were motivated by his desire to include "some energy diagram work" in the materials. He suggested that the topic should start with an introduction to warming up as energy changes. This would lead to a review of the Sankey-type diagrams, modified to take account of both effective and ineffective outputs of thermal energy. The existing work on conduction, convection and radiation ("the mechanisms for the delivery of thermal energy") would follow. Next there would be a section on the "why" diagrams to look at changes which happen by themselves driving other changes which do not happen by themselves. As before, the topic would conclude with the investigation, though Sankey and "why" diagrams would also be included as interpretative frameworks. The combination of the two sort of diagrams, according to Ivan, would get pupils thinking about *"why the energy ends up where it ends up and then how much of it ends up in any particular place"*.

Some teachers in the department were not convinced that the 'why' diagrams were, as Ivan put it, 'doable'. So, Ivan tried out the activities a few weeks ahead of his colleagues, and shared his experience with them about what 'worked' and what did not work. The following is a description of Ivan's first lesson.

Ivan's plan had been to remind the pupils of the 'energy transfer diagrams' and the 'energy flow diagrams' they had met in the previous year then to introduce to them the new sort of 'why' energy diagram. However, as the pupils did not seem to remember how to draw the 'energy transfer diagrams' Ivan started the lesson by talking about how energy changes from one form to another and showing the pupils how they could draw a simple 'energy transfer diagram' for a pen falling, sketching this on the board:




He then went on to introduce the "why" diagrams. For the pen falling he built step by step the following two Before-After pictures:



> *"Well, I built it for them, because I wanted them to see that there was a structure inside the diagram. So, that the diagram was representing a process for us rather than just a fixed state of affairs."*

Ivan then said about these two diagrams that what energy the left loses the right gains.

> *"This* [the right diagram above] *you have to provide some input - you need to pump energy in to make it happen. This* [the left diagram above] *happens by itself"*

And thus he added the arrows of spontaneity (one pointing up and one pointing down) on the above pictures and linked the two pictures.

After the lesson Ivan admitted that he had hesitated about linking the two diagrams. He was afraid that he had gone too quickly from building up one diagram to talk about linking two of them, but he had decided to do it in order to describe the whole process rather than just part of the process.

Ivan then moved on to one of the project's activities for pupils called 'Concentrated energy'. The aim of this activity, according to the project, is "to introduce the notion that we can think of a 'concentration' of energy in the same way as a concentration of a substance". Ivan explained his rationale for using this activity

> *"I then needed them to have some background of why the pen wasn't going to start moving by itself. So we needed some notion about spreading and randomness built in. [...] So, the goal of the lesson rests in trying to get the notion of things being spread out linked to their thinking about energy changes. Cos that's the first time they've really begun to think about irreversibility at all."*

On the project's worksheet there were two activities for the pupils to do. For the first they had to repeatedly dilute a coloured liquid until they could no longer see it and for the second they had to do the same thing, only this time with hot water until they could no longer notice the temperature changing. For both activities they had to answer some questions which aimed to make the point that while matter and energy spread out they do not disappear, even though they may have spread out so much that they are undetectable.

During the activity Ivan kept trying to make the pupils see that the two sets of questions on the worksheet were identical, and that therefore their two sets of answers were linked. In the interview after the lesson he expressed his doubt about whether the majority of the pupils had made this link. The activity had lasted more time than Ivan had anticipated and as a consequence there had been no whole-class discussion of the results, which could have achieved some recognised class consensus about the similarity of the sets of experiments. Ivan thus declared his intent to make this link more obvious next time he used the activity, so that pupils were encouraged to use similar arguments in their answers and the analogy between the spread out dye and the spread out energy got more strongly established.

At the end of the lesson Ivan gave the pupils a worksheet titled 'Things which happen all by themselves' to do at home. This worksheet contained some examples of things cooling down next to the corresponding abstract diagram labelled 'temperature difference decreasing' and also the diagrams of something slowing down, a spring relaxing and something falling. The pupils were asked to write three everyday examples of changes which happen all by themselves and might be described well by each of these latter diagrams.

In the after-the-lesson discussion we had with him, Ivan admitted to having once more experimented when he had given the pupils this latter activity.

> *"I've given little introduction to these* [diagrams] *and the extent to which they* [the pupils] *can manage to find three or four common exemplars of those will tell me the extent to which I actually need to think about being able to deal with the diagrams as separate or see them needing to be linked."*

He however also expressed his worry and discomfort for having too much rushed the new pictures and ideas in the lesson and attributed this rush to the fact that he was trying to slot them into a scheme of work which already existed.

*Activity Resource 3*

# Transformations' of curriculum innovation: dimensions of analysis

The following is a summary of the analysis of the STTIS research about the factors that affect transformations of curriculum innovation. This research was based on a variety of different kinds of curriculum innovation, of which the work on energy considered in these workshops was a part. In the first part of the workshop, you considered four different kinds of factors related to the nature of transformations: Content, Beliefs about learning, Values, and Contexts, customs and constraints. These factors cannot be seen in isolation, however, and there is overlap between them. In the analysis, three broad dimensions will be discussed. The links to the activities in the first workshop are given in parentheses.]

- The relationship to accepted subject content [Section C]
- Teachers' convictions (beliefs about learning, and values) [Sections D and E]
- Teachers' habitual practices, and those expected of them (contexts, customs and constraints) [Section F]

## The relationship to accepted subject content

An important issue is teachers' concern for the match of an innovation to existing syllabus content. This is especially true in the cases where the 'up-take' of an innovation is optional. The innovation is easier to accept when the content-distance between the 'new' and 'old' knowledge is rather small. Moreover, innovations are easier to accept if they address:

- Curriculum areas not presently taught but which teachers would value. (Note that in many systems this would involve the development of new curricula so that work on these new areas would not be seen as distracting from the syllabus content).
- Those curriculum areas currently taught but where teachers believe that present methods are ineffective. Experimentation is more likely to be viewed as reasonable if what exists is felt not to be good.

How may the 'new' be seen in relation to the 'old'. The following two kinds of transformation were observed in the research:

**'New' is considered as an add-on to the 'old'.** The innovation is 'added to' rather than 'substituted for' something else. In this case, certain ideas of the innovation are included, but the adoption of the general framework of the innovation is ignored or deferred and thus possible contradictions between the new and the old are ignored. There is a good deal of switching between using the innovation and not using it depending on the context. 'Old' and familiar contexts attract 'old' and familiar strategies.

**The 'new' becomes like the 'old'.** Teachers transform the use of an innovation to one as close as possible to a more traditional structure of content. The existing framework remains unchanged, and the new ideas are adapted so that they may be accommodated within it.

The teacher's perception of the degree to which an innovation 'fits' the required subject content is critical to its acceptance. If the fit is not good enough, the use of the innovation will be transformed to make the fit closer. Where the innovation carries with it both a new 'tool' *and* new subject matter, and the latter is too far from what a teacher expects or understands, both are likely to be transformed. But against this, there are some successful 'curriculum packages' which put together new tools, contents and practices in a convincing way.

## Teachers’ convictions (beliefs about learning, and values)

It is striking that, when asked, most of the teachers in the case studies express strong convictions and beliefs about what should be taught in the classroom, and about what can facilitate learning and engage students. It seems that teachers develop strong views, on which they act, and any proposal which runs counter to those views is unlikely to succeed. In consequence any proposal for the use of an innovation is likely to meet objections on the grounds of some conviction, which will have to be overcome if the proposal is to succeed. Some characteristic kinds of conviction are:

**Convictions about goals for students:** Teachers, as one would expect, have strong views about what ideas can be taught with a particular age of pupils. It was not the case that all teachers agreed about what would be easier or more appropriate with a particular age of pupils; nevertheless, they seemed to repeatedly appeal to this notion of easiness or appropriateness for their students, when they talked about using a particular approach.

**Convictions about time:** The notion of time, whether this was preparation time for the teachers, preparation time for the pupils, or teaching time that an innovation would require, was an important consideration for the teachers. This played an important role when the implementation of an innovation was considered optional by the teachers.

## Teachers’ habitual practices, and those expected of them (contexts, customs and constraints)

Every case study shows a teacher trying to achieve a fit between the use of the innovation, and the habitual classroom practices with which that teacher and his or her class are familiar.

**Old resources and practices:** Where the innovation itself was not accompanied by detailed guidelines or teaching material to use, the intentions of the innovation were liable not to survive into the actual teaching event when they were in conflict with or marginal to the teacher’s practices.

**Integration of the innovation into the teaching process:** The extent to which an innovation is integrated with other teaching materials varies widely. Innovation may be isolated from the curriculum, and may happen as single’ one-off’ lessons. On the other hand, innovations may be integrated cautiously, through small-scale integration of new ideas into old materials.

**Examinations and syllabus requirements:** It seems to be of paramount importance that teachers perceive the innovation as addressing or helping towards fulfilling the examination syllabus requirements.