# TEACHING SCIENCE IN SCHOOL

## La main à la pâte resource materials for the primary classroom

INSTITUT DE FRANCE
Académie des sciences

# Teaching Science in School

La main à la pâte resource materials
for the primary classroom

A Collaborative Project of

Southeast Asian Ministers of Education Organisation
Regional Centre for Education in Science and Mathematics
(SEAMEO RECSAM)

with

Académie des Sciences France

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# Preface

*In June 2002, after praising the La main à la pâte operation, 'the propitious initiative of Geroges Charpak and the Academy of Science, taken over by the National Institute for Educational Research' (INRP), the Minister of National Education announced the setting up of the plan to renew the teaching of science and technology in schools*[1]*: 'I am putting in place a very broad operation. It will be established in primary schools and will foreshadow the changes which I intend to carry through to the Collèges and then to the Lycées'.*

*In February 2002, new teaching programmes for primary schools were published*[2]*, which took effect at the beginning of the school year 2002-2003. The titles of these programmes, 'Discovery of the World' (nursery school and the 'basic skills' cycle) and 'Science and technology' ('more advanced skills' cycle) are consistent with the recommendations of the renewal plan.*

*One does not have to be a specialist to conduct scientific activities in the primary school. The experimental investigation work may be simple, the knowledge to be imparted is accessible. The teacher is able to stimulate and share the pleasure and the curiosity of the pupils, and to encourage a reasoned exploration of the world around them, which they can put into words, into pictures and into arguments. The universe of science, in which scientists seek new discoveries and engineers create new objects and products is truly within the reach of versatile school teachers and their pupils.*

*As a tool for the implementation of the French renewal plan for science teaching launched in 2000 and the new French curriculum for primary school of 2002, this book is designed to assist teachers in their development of teaching based upon questioning and upon experimentation by the pupils themselves.*

*Each module in this book is mapped to the position of the subject matter in the new teaching curriculum: Cycle 1 for children of 2 to 5 years old; Cycle 2 for children of 5 to 8 years old; Cycle 3 for children of 8 – 11 years old and College level for children of 11 – 15 years old. The provision of these levels guides teachers from other countries in using the resource materials in accordance with their level of difficulty and the age group of the pupils in their science classrooms*[3]*.*

*The authors*

[1]Departmental note no. 2000-078 of 8 June 2000, published in the Official Bulletin no. 23 of 15 June 2000.
[2]Decrees of 25 January 2002, published in the Official Bulletin special issue no. 1 of 14 February 2002.
[3]The final paragraph is an extension to the original Preface in French.

# Foreword

*The French version of Teaching Science in Schools was first published in the year 2002, in line with the implementation of a new national curriculum to revitalise the teaching of science in primary schools in France. The publication of this English version is a collaborative effort involving the Académie des sciences France, Academy of Sciences Malaysia and SEAMEO RECSAM with the aim of promoting and disseminating the La main à la pâte inquiry-based science education programme to countries in the Southeast Asian region.*

*The involvement of SEAMEO RECSAM with La main à la pâte dates back to 2003 with a visit by a delegation to France to study the La main à la pâte programme implemented in primary schools across the country. Since then, the centre had hosted three La main à la pâte workshops for science educators in 2004, 2005 and 2006 respectively. The first two workshops were made possible through the funding procured from the French Regional Cooperation. The workshop in 2006 was jointly supported by Académie des sciences France, with the help of the French Ministry of education, and Academy of Sciences Malaysia. The workshops had been successful in promoting understanding and appreciation of the La main à la pâte philosophy and approach to science teaching and learning among school teachers, officers from the ministries of education as well as university and college lecturers of the SEAMEO countries.*

*As the teaching and learning materials posted at the La main à la pâte website are mostly written in French, it is envisaged that the publication of this English edition would bridge the language gap and subsequently provide the much needed resources for direct use in the classroom. The materials in this publication would also find its place in enhancing the capacity of teachers in their efforts to make learning science a stimulating and meaningful experience for their students.*

*The methods suggested in this book provide valuable exemplars that model the constructivist inquiry-based approach in the teaching and learning of science. These exemplars are not meant to be prescriptive, and teachers are encouraged to be creative in adapting and adopting the ideas where appropriate to fit the learning environment of their respective classrooms.*

*It is hoped that this publication would not only add to the literature of La main à la pâte but also serves as a catalyst for practice, implementation as well as research and development of this approach in primary schools in the region.*

*SEAMEO RECSAM would like to express our sincere gratitude to the Académie des sciences France, Ministry of Education, France, Academy of Sciences Malaysia, Ministry of Science, Technology and Innovation Malaysia, Ministry of Education Malaysia and all parties that have contributed to the success of this publication.*

*DR AZIAN T.S. ABDULLAH*
*Director, SEAMEO RECSAM*
*30 June 2007*

# Introduction

The purpose of this introduction is to provide orientation for teachers; it is followed by descriptions of the teaching of seven modules. Spread across the different educational cycles and the different areas covered in the new teaching programme, these modules provide explicit examples of the implementation of the active approaches recommended.

This book is designed to help the teacher to teach science and technology in a reformed manner, from the point of view of both the educational method and the required elements of scientific knowledge. It is in no way a manual for the teaching of science in primary schools. The modules which themes are taken from the very heart of the programmes are intended to provide the committed school teacher with a tool with which to embark upon the path of renewing the teaching of science. It is assumed that the teacher will consolidate his/her approach over the course of these modules and will be able to proceed progressively with the aid of of the tools already available and[1] those which will be provided in the future.

Consideration of the development of the pupils' ability to express themselves, both orally and in writing, lies at the centre of the teaching encouraged by the science and technology programme. The section `Science and language in the classroom' below presents various recommendations to that effect. As far as the French language is concerned, this aspect is developed throughout the modules described in this document[2].

The work on language which inevitably stems from a scientific activity may also be extended to the foreign or regional language studied in class. The module `What time is it in Paris, Beijing or Sydney' provides an example of this, involving statements or syntax structures which should be learnt during the programme.

This introduction is due to the technical group associated with the national committee for the following through of the plan to renew the teaching of science and technology in schools.

The modules to be taught result from the collaboration between that technical group and a team from *La main à la pâte* (Academy of sciences-INRP-École normale supérieure ULM).

The publication of this work results from the collaboration of people with a very varied involvement: teachers, teacher training college (IUFM) teachers, regional inspectors, scientists. The close collaboration within a single team of specialists in the areas covered and those working on the ground, is designed to ensure that the scientific quality of the book and its pedagogic quality are equally high. The fact that its signatories include the Ministry for Youth, National Education and Research - School Education Directorate, and the Academy of Sciences - *La main à la pâte,* attests to the important role played by *La main à la pâte* in the context of the plan to renew the teaching of sciences and technology in schools: the *La main à la pâte* operation is being followed up. It retains its own dynamics and its own specific character, due particularly to the association of scientific partners. Built into the plan as an innovative central point and focal point for diffusion, it is an essential element[3]

## Benchmarks for the teaching of a module[4]

The following outline is intended for teachers. The aim is to provide them with benchmarks for implementing an approach to teaching in the spirit of the renewal of the teaching of science and technology and that of the 2002 programmes.

[1]Notably on the website www.inrp.fr/lamap

[2]The pupil documents reproduced here may contain writing mistakes or syntax errors. These are of course records as they were first written before reworking with the teacher.

[3]Extract from the common declaration of 8 September 2000, signed by the permanent secretaries of the Academy of sciences, the director of school education and the president of the national committee for the following through of the plan to renew the teaching of sciences and technology in schools. The complete text can be found online at www.educsol.education.fr

[4]The approach corresponds to the scheme of `From questioning to knowledge via experiment', where the word experiment' here is taken in the broad sense of the experimental investigatory approach.

It is an operational educational document which does not claim to define the scientific methodology nor to comprehensively cast in concrete the progression from the problems, to the investigation, and to the final structuring. Having its roots in active methods, the approach proposed here can be compared with that recommended for the solution of problems in mathematics. As far as presentation is concerned, five essential component phases have been identified. The order in which they succeed one another is not a rigid linear framework which has to be adopted. Movement back and forth between these phases, depending on the subject, is completely desirable. On the other hand, each phase identified is essential to ensure that the pupils' investigation is well thought through.

## Various aspects of an investigatory experimental procedure

The approach called for under the plan for the renewal of the teaching of science and technology in schools is based around two principles: unity and diversity.
- Unity: this approaches involves questioning the pupils about the real world: phenomenon or object, living or non-living, natural or man-made. This questioning leads to the acquisition of knowledge and know-how, following an investigation undertaken by the pupils under the teacher's guidance;
- Diversity: the investigation undertaken by the pupils may rely on various methods, including during any one lesson:
- direct experimentation
- physical implementation (construction of a model, search for a technical solution)
- direct observation or observation with the help of an instrument
- research using documents[5]
- survey and visit.

The complementarity of these means of accessing knowledge should be balanced according to the subject of the study.
Whenever possible, from a practical and deontological point of view, direct action and experimentation by the pupils should be encouraged.

[5]See the next section `Status of documentary research and CIT'

[6]Consisting, in general of several lessons devoted to the study of a single subject.

## Basic structure of a module[6]

### Choice of an initial situation

- Parameters chosen as a function of the programme objectives.
- Pertinence to the cycle plan drawn up by the council of teachers of the cycle.
- Productivity of the questioning to which the situation may lead.
- Local resources (in terms of materials and documentary resources)
- Centres of local interest, topical or issuing from other scientific and/or non-scientific activities.
- Relevance of the study undertaken, bearing in mind the interests of the pupils themselves.

### Formulation of the pupil questioning[7]

- Work led by the teacher, which may possibly help to reformulate the questions to ensure that they make good sense, to recentre them in the scientific domain and to improve the pupils' oral expression.
- Selection of productive questions to be exploited, directed and justified by the teacher (that is, questions which lend themselves to a constructive approach, taking into account the availability of the experimental and documentary materials and leading to the acquisition of skills written in the programme).
- Emergence of the pupils' initial notions[8], addressing any divergence of these ideas in order to encourage the class to take the given problem to heart.

### Development of hypotheses and design of the investigation

- Management of how the pupils are grouped together (at various levels according to the activities, from pairs to the full class group) by the teacher; instructions given (functions and behaviour expected in the groups)
- Oral formulation of hypotheses in the groups
- Possible development of schemes[9] designed to validate or invalidate the hypotheses.
- Production of written work stating the hypotheses and schemes for testing them (text and diagrams).
- Written or oral formulation of predictions by the pupils: `what I think will happen', `for what reasons?'
- Oral communication to the class of the hypotheses and testing schemes proposed.

[7]See the texts `From questioning to knowledge, via experimentation' and `The teaching of the sciences in the primary school', online at the address www.eduscol.education.fr.

[8]The teacher's should be such that the initial conceptions are not hidden from sight. .

[9]In the broad sense, including in particular a construction plan.

### Investigation undertaken by the pupils
- Periods of internal discussion among the group of pupils; ways in which the experiment may be implemented
- Monitoring of the variation of the parameters
- Description of the experiment (diagrams, written description)
- Reproducibility of the experiment (pupils list the experimental conditions).
- Management of the pupils' personal written records.

### Acquisition and structuring of knowledge
- Comparison and interrelation of the results obtained by the various groups, by other classes, ....
- Confrontation with established facts (another form of recourse to documentary research), respecting the levels of formulation accessible to the pupils.
- Search for the causes of any disagreement, critical analysis of the experiments undertaken and proposal of additional experiments.
- Written formulation of new knowledge acquired by the end of the module, put together by the pupils with the help of the teacher.
- Production of work designed to communicate the result (text, graphics, model, multimedia document).

# Status of documentary research and ICT[10]

The methodology implemented by the plan is described in the official bulletin no. 23 of 15 June 2000:
- The pupils build up their skills through active involvement in scientific activities.
- They observe a real-world phenomenon in their close environment and formulate their queries around it.
- They conduct considered investigations implementing specific experimental approaches, complemented where necessary by documentary research. It is important that the pupils should experience these two complementary paths.

The teaching of a module conforms with the objectives of the renewal plan and has been described in the above document. The object of the following paragraphs is to describe how documentary research can and must be involved to complement an approach which leads from questioning to knowledge via experiment.

[10]Information and communication technology. These considerations fall under the framework of the plan for the renewal of the teaching of the sciences and technology in the school.

Let us first state the various interpretations which can be put upon `documentary research'.

## Documentary research

Using the public or school library, a dictionary, an encyclopedia, or the Internet, in order to answer `productive' questions from the class and to solve scientific problems which is not possible to solve in full through experiments, the pupil should:
- know how to use a dictionary to look up the word which may provide him/her with the elements of an answer;
- be able to use an index in an encyclopedia;
- understand the organization of a library and be able to find a number of accessible and interesting works there;
- know how to use the table of contents in a book;
- know how to extract the interesting information from an article;
- be able to interpret the text, diagrams and illustrations in an article;
- be able to formulate an effective query in an appropriate search engine and know how to distinguish responses which may be of interest for the investigation.

In fact, these skills are established progressively and will be reinforced throughout student life, by teaching, through interdisciplinary schemes such as TPE, PPCP and TIPE[11], and in the writing of university theses....

### Research using documents[12]
With the multiplication of images and screens, we encounter contradictory and often passionate reactions concerning their educational impact. Where do we draw a sensible line between those who believe in informal education (the screens are there anyway, young people gain more from them than we can imagine...) and those who fear for the moral and intellectual health of children?

### The psychological impact of documents
**-** Historical impact**:** the introduction of audovisual educational documents from the beginning of the century has been marked by a peak, in particular, with the short silent films of the 1970s which presented phenomena for the pupil and the class to interpret. The arrival of television programmes, subsequently recorded on VHS, reduced the active role of the pupil considerably.

[11]Translator's note. TPE (Travaux Personnels Encadrés), PPCP (Projet Pluridsciplinaire à Caractère Professionel), TIPE (Travaux d'Initiative Personelle Encadrés) are multisciplinary schemes in secondary education, designed to provide practical and work experience.
[12]In particular, pictorial documents.

- Geographical impact: it turns out that the quality of educational television around the World is very dependent upon the teaching schemes which accompany the programmes. Magazines and then Internet websites propose numerous ideas for activities based on broadcast images (Téléquébec, BBC Education, NOT and France 5 offer documents to accompany educational programmes).
- Educational impact: what status and what role should be given to documents in comparison with the study of real phenomena, directly perceptible to pupils? What type of approach to teaching should be used?

### Which documents?

There is a need to distinguish between interpreted explanatory documents, which reveal and give a meaning, and uninterpreted raw documents where it is up to the pupils to search for a meaning (example: an X-ray of a fractured leg; pictures of a volcanic eruption with commentary or fast-forwarded images of the development of a plant from the flower to the fruit).

### When should they be used?

- To assist with the development of questioning in a motivating fashion. Examples: pictures or images relating to a topical news item (earthquake); pictures of a professional activity (of an archaeological dig, to introduce work on fossils and records of evolution), etc.
- To provide complementary information to be analysed by the pupils. Example: medical imagery of the human body or the examples of noises referred to earlier.
- To help in the development of a collective summary, with the class reformulating what they have noted in their experimental notebooks, on completion of research work. Examples: all explanatory documentaries which are often spinoffs from television programmes (*C'est pas sorcier, E = M6...)* or all synoptic sequences of images designed to be explanatory (with the difficulty of having to explain the codes or the analogous images used).
- As feedback to the knowledge acquired into other examples or for evaluation purposes. For example: sequences or images showing sources of energy other than those covered in the course, documents extending to broader problems on health education or the environment (for example, based on a very detailed study of the pellets from birds of prey, in a documentary on the ecological importance of protecting birds of prey...) or on the impact of everyday acts on the equilibrium of certain food chains.

### Complementarity between real objects and phenomena and documentation

Certain phenomena or objects are not directly perceptible because they are too large (for example in astronomy), too small (microbes), too long (growth of a tree), too short, too rare or too dangerous (eruptions, earthquakes), too expensive (rocket) or belong to the past (history of sciences and technology).
The real world itself can be investigated from different angles: via observations, experimentation, comparisons....
But complementary documents may enrich this wonderment before the real world. For example, a sequence on an ice floe, a glacier, an avalanche or the icing over of a stream would be interesting to analyse as a complement to an experimental introduction to the changes of state of water.
A switching back and forth between the concrete and the abstract, between scientific and technical phenomena and their applications (for example, in the professional world or in the workings of objects which the pupils use each day) would be fruitful.

The renewal of the teaching of the science and technology in the school is directed towards the acquisition of knowledge and know-how, based on a proper balance between the observation of real phenomena and objects and direct experimentation and the analysis of complementary documents, in order to educate pupils in scientific methods of accessing knowledge and to accustom them to identifying and checking their sources of information, thereby developing their critical and civic spirit.

The role of information and communication technology (ICT) within the plan can be stated with the same logic: `Direct experimentation undertaken by the pupils is the basis for the approach implemented. From this point of view observation of the real world and action on it have priority over recourse to the virtual world'.

This consideration in no way decreases the interest of resorting to ICT, whether to refer to documents which complement direct observation or to search for references which will make it possible to compare experimental results with established facts.

## Science and language in the classroom

In the approach which underlies the activities of the class in science and technology, language is not the primary object of study.
But in the alternation which the teacher organizes between observation of the real world, action on the real world, reading and production of various pieces

of writing, the pupils gradually build up language skills (oral and written[13]) whilst developing their thoughts at the same time. Individually or collectively, in science, language is called upon:

- to formulate knowledge which is being built up: to name, label, classify, compare, develop references and transmit;
- to establish relationships: to interpret, reorganize, give meaning to;
- to assert a point of view: to convince, argue
- to interpret reference documents: to research, document[14], consult

The pupils' initial ideas can be expressed equally well orally or in individual writing, but this will often only be complete with the undertaking of a first experimentation. This enables the teacher to better perceive the pupils' implicit theories, and based on these, to better identify the scientific nature of the problem posed.

## Oral work

Leaving the design of the actions and the organization of comparisons to the pupils, makes it possible to set up very useful and meaningful oral exchanges in the class.
Expression in speech encourages thinking which is at the same time considered and spontaneous, divergent, flexible and propitious for invention. This implies that the times for talking should be written into the schedule through questioning by the teacher and the organization of work in pairs.

## From oral to written work

The plan developed by the pupils requires that certain elements of the discourse be cast concretely as provisional or definitive records, as notes and lists, and as messages to be communicated.

With this falling back upon writing, oral expression can thus be assured, remodelled, rewritten and related to other writing. Language, the vector of thought, allows one to anticipate actions. When oral work precedes written work, the pupil's discourse passes from a heavily implicit spoken language to a more precise language conforming to the monosemy of scientific language and incorporating various forms of written work: diagrams, graphics, paragraphs, underlinings,....

Writing encourages the transition to more highly developed levels of expression and conceptualization.

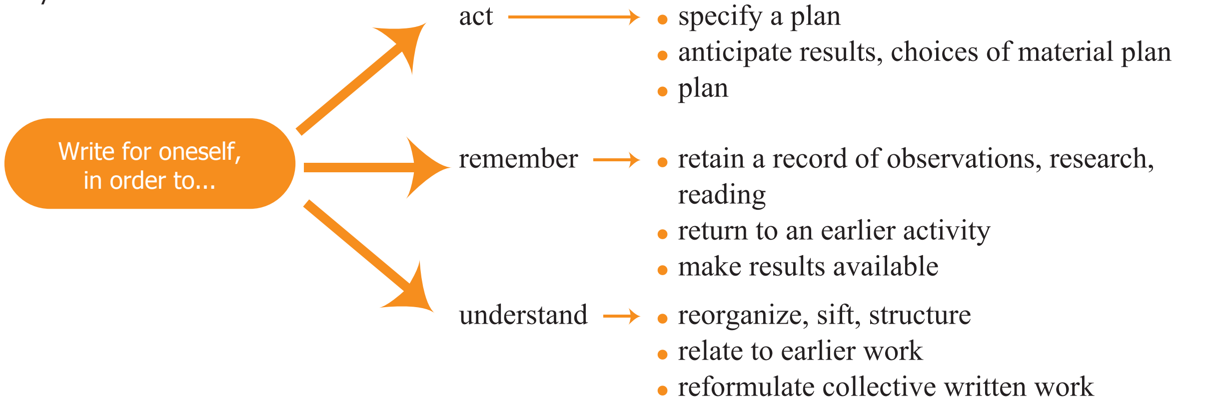
## Written work

Writing invites one to be objective, to distance oneself. The production of written work for others, requires one to make the work interpretable in a referential system which is no longer the property of its sole author, and thus to clarify the facts on which it relies. In a science class, the main aim of the generation of written work is not to demonstrate an ability to write, but to promote the pupils' scientific skills and to facilitate the educational guidance by the teacher.

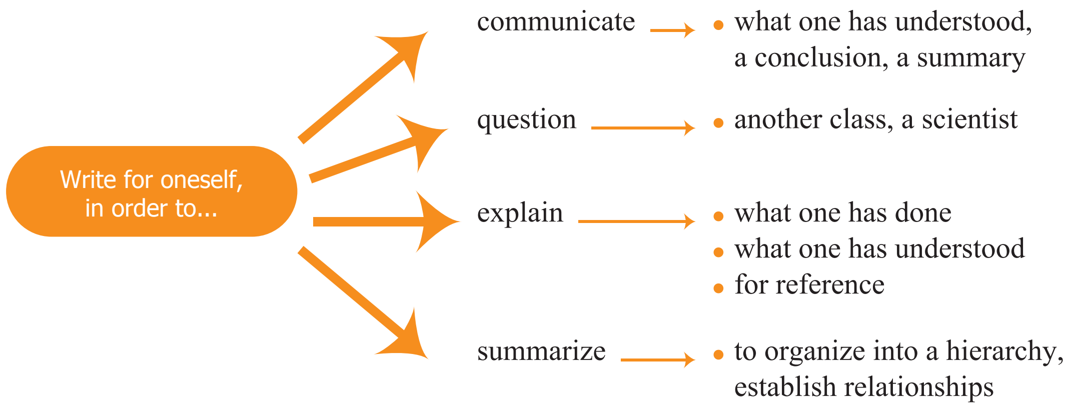
The pupils are invited, individually or in groups, to produce written work which is accepted as it is and used in the class as a means of improving learning.

In addition to the narrative text, very commonly used in schools, other forms of writing are introduced. This renewed relationship with writing is of particular interest for pupils who have no spontaneous desire to write or are unaccustomed to achieving success in this area.

Why write?




[13] Including pictures and diagrams.
[14] See `Status of documentary research and CIT'.




### The experimental notebook

This belongs to the pupil; it is therefore the special place for writing for oneself, in which the teacher does not impose his/her authority; but it is also a personal tool for building up skills.
To this end, it is important for pupils to retain their notebooks throughout the cycle: they should be able to find the record of their own activity and their own thoughts there, to search for elements with which to build new skills, for points of reference which can be called upon or improved.... The notebook includes not only the pupil's personal records but also collectively drafted written work which has the status of fact, together with the pupil's reformulation of this latter work.
At the same time, pupils should be under no compulsion to record all of their trial and error and unsystematic work. Their criteria for deciding whether or not to keep a record should relate to the relevance of the written work to what was intended and not to the intrinsic quality of the writing as such.
Written work of different status will gain from being easily identifiable by pupils: for example, whenever possible, the class summary will be processed on computer and then photocopied for everyone.
In the case of writing in the sciences, pupils should bring all their efforts to bear on the content of their knowledge brought into play and on their activity (experimentation, interactions,....). At the same time they will incorporate words, symbols and codes specific to texts of a scientific nature.
The need to involve the pupils in the work calls for a reasoned tolerance on behalf of the teacher. The specific skills associated with the production of written work in the sciences are built up over a long period.
The continual and well-thought out coming and going between personal writing and institutionalized writing encourages the pupils to appropriate the characteristics of the scientific language for themselves:
- codified representations
- organization of the written work linked to the establishment of relationships (titles, lay out, connectors,...) and in particular to the relationship of causality;
- use of verb forms: present, passive.

### The role of the teacher

The teacher will supply help in various forms:
- in response to a request;
- posting of a glossary, relating to an identified area, constructed as the need arises;
- by suggesting tools for recording observations, such as:
  - sheets of squared or lined paper, which help the transition to graphics,
  - coloured self-adhesive stickers which help statistical understanding (clusters of points),
  - tracing paper so that elements deemed to be relevant can be extracted or all or part of a document constructed earlier or selected during research can be reused;
- by suggesting frameworks for the writing, so as to provide guidance without imposing a straitjacket:
  - double-entry tables,
  - calendars ;
- by organizing sessions for the communication of experiences and summarizing within the class and with other classes, to allow the pupils to test the effectiveness of their choices;
- by making documents, aids to analysis, references and written material of a complex form whose usage is well identified available to the pupils

These aids will be effective in the making of comparisons.

## Intermediate written work

Produced by the groups or following interactions between the pupils, this will permit the transition from `I' to `We', with the generalization (transition from `We' to `One') being made, in general, in the whole class, with the help of the teacher. This will either permit each pupil to return to his/her own route ahead or allow the development of proposals for the summarizing in class. It is enriched by all the documents made available to the pupils.

## Class documents

These rely on the written material produced individually and by the groups. The teacher adds the organizational and formalizing elements which make it possible to solve the problems raised when the intermediate tools were compared and contrasted.

The level of formulation of these documents will be compatible with the levels of formulation of the established facts chosen by the teacher.

Finally, it is important for the teacher to allow each pupil to reformulate the approved collective summary in his/her own words using aids of his/her own choice.

| Personal writings to | Collective writin gs of the groups to | Collective writings of the class with the teacher to |
|---|---|---|
| - express what I am thinking<br>- say what I am going to do and why<br>- describe what I am doing, what I observe<br>- interpret the results<br>- reformulate the collective conclusions | - communicate to another group, to another class, to other classes<br>- ask questions about a plan, research, or a conclusion<br>- reorganize, rewrite<br>- pass from a chronological order associated with the action to a logical order associated with the knowledge in play | - reorganize<br>- relaunch research<br>- ask questions, referring to other writings<br>- list the factual elements together with the tools for describing them<br>- institutionalize that which is to be retained |

Translator's Note
Readers unfamiliar with the French education system may profitably consult, for example, the website http://www.discoverfrance.net/France/Education/DF_education.shtml

# Is air matter ?



This module concerns the study of materials at the end of cycle 2 or the start of cycle 3 (CE1-CE2). It makes reference to fact sheet no. 3, `Air' and to the video sequences provided with the CD ROM. With reference to the subsection of the Introduction entitled `Benchmarks for the teaching of a module', the key elements of each lesson are illustrated by a short video.

This module has been taught as part of a project of classes at the level CE1-CE2. By project, we mean a set of activities associated with investigations by the pupils of possible solutions to a problem which has been collectively established.

We shall distinguish between:
- the problem for the teacher: how to convince the pupils that air is matter;
- the problem for the pupils which provides the direction for their work in each lesson.

Based upon the initial situation suggested to the pupils by the teacher, in the form of questions and/or challenges at the beginning of each lesson, the pupils will discover questions which they would not have asked themselves without these situations and which, after reformulation, may lead to the emergence of problems whose solution will constitute the essence of the lesson for them.

It is during these activities that the pupils will gradually build up the desired concepts (here, air is matter in the same way that a solid or a liquid is). The linguistic aspects, both oral and written, of the practical experimentation are emphasized in this approach. They give rise to a recurrent activity of analysis and reflection, and thus form part of the conceptualization.

Beyond its conceptual objective concerning the material nature of air, this document is intended to illustrate:
- how a teacher can manage the different phases of this type of activity;
- the ability of the pupils to think up an experiment, to perform it and to draw pertinent information from it, even when the experiment does not `satisfy' the initial hypotheses;
- the place and role of the various written material produced as part of the activities (long-term management of an experimental notebook).

## Position in the programmes

- In cycle 1: the pupil begins to relate to the world via the senses. The activities proposed will enable him/her to develop his/her perception and, in particular, tactile perception. In this sense, wind (moving air) provides a first means of demonstrating the existence of air. The well-thought out construction of objects using the wind (a windmill...)[1] can be used to establish this existence.
- In cycle 2: discovery of the world of materials. Solid and liquid materials have been encountered and handled, and some of their properties have been discovered. The pupils will now progressively establish the existence of matter which is not visible, which can be retained, can move and can act, even when stationary. They will also encounter this matter when they study the five senses or manifestations of life in animals (conditions necessary for keeping animals, study of forms of movement, such as the flight of birds).

| Extracts from the programme | Extracts from the application document | |
|---|---|---|
| | **Specific skills** | **Remarks** |
| **Material**<br>- Gaining an awareness of the existence of air, first manifestation of a form of matter which is not a solid or a liquid (the study of the material nature of the air and the construction of the gaseous state form part of cycle 3). | Ability to show that spaces which are commonly described as `empty' are filled with air.<br>Ability to create and interpret a number of simple situations bringing into play the following rules:<br>- air can move;<br>- air does not vanish and does not appear out of nothing: if it seems to vanish from one place that is because it has moved to another place.<br>The knowledge that wind is the air in movement. | At the start of cycle 2, pupils are able to formulate reasoned arguments about the retention of solids or liquids; the objective is to lead them to construct a similar reasoning in the case of air. This relies, in the first place, on situations in which air is manifest in a perceptible way; the aim is to recognize the presence of air, even when it is stationary. |

- In cycle 3: study of matter: air and its mass. The fact that air has a mass will be established, another invisible substance, water vapour, will be met. The notion of the gaseous state will be built up gradually. Considerations regarding the adaptation of living beings to their environment will make it possible to view air (breathing, circulation) from a vital point of view.
- At Collège: a property of air as a gas is demonstrated, namely compressibility. Study of air from the chemical point of view (combustion, particular model) leads to a deepening of knowledge of materials. Introduction to other gases (atmospheric oxygen, atmospheric nitrogen), both in chemistry and in the life sciences permits a deepening of the notion of the gaseous state. Finally, studies, for example, of green vegetables or of the conditions in which animals are reared, will lead to air being seen as central to life.

### Knowledge and know-how which pupils should acquire or have acquired as a result of the module

- Ability to differentiate between the states of matter according to some of their properties.
- An initial awareness of the existence of a new state of matter, the gaseous state. Air is a material in the gaseous state.
- Ability to design and implement an experimental procedure for solving a problem.
- Realization of the first stages of an experimental approach.

[1] The module `How do we know where the wind comes from?', which is intended for cycle 3, includes the building of a weather-vane.

## One possible way in which the module might be taught

| Lessons | Initial question | Activities undertaken with the pupils | Knowledge and know-how brought into play | Linguistic activities |
|---|---|---|---|---|
| Lesson 1 | What is in the bags hidden inside the boxes? | Handle the bags containing different materials without seeing them, feel, experience sensations, characterize these, name them, then pass on information about them and compare them with those experienced by fellow pupils. | A sensory approach to the states of matter.<br>Distinguish these states by some of their properties: rigid, solid, soft, heavy, light, heat conduction (cold or warm feeling), etc. | The pupils describe what they have felt orally (name, describe).<br>A collective written record is drawn up. |
| Lesson 2 | What do we know about air? | The teacher arranges a collective discussion of the pupils' ideas about air: where do we find it?<br>What is its purpose?, etc. | Pupils' ideas about air.<br>Awareness of the fact that not everyone in the class agrees on the existence of air, where it is to be found, its role, etc. | Debate with fellow pupils.<br>Give expression to spontaneous notions built up from everyday experience.<br>Draw up a collective written record, maintaining a distance from the spontaneous notions. |
| | Can you catch air? | Think of a way of filling a bag with air: open the bag with the class; blow into it; run in the playground with the bag; etc. | Know how to perform a simple experiment: open the bag, fill it with air, seal it.<br>Air exists and is matter because one can catch it and fill a container with it. | Describe an experimental procedure orally. |
| Lesson 3 | How can one prove that the bag contains something? | Think of an experiment to answer the initial question.<br>By analogy with situations in everyday life, the pupils suggest `emptying' the bag after piercing it.<br>They think they feel the air coming out. The perceived failure of this experiment leads the teacher to organize a debate to enable the pupils to overcome this setback by thinking up new experiments. | Perform an experiment according to an established procedure. Know how to extract information from it.<br>Realize that an experiment `is not working': air is not a palpable substance like a solid or a liquid. First distinction between gaseous and liquid states.<br>Challenge the experimental procedure in order to work out a new one. | Write down an experimental procedure in small groups.<br>Present it to the whole class and argue it through. |
| Lesson 4 | How can one recover the air from the bag? | Think of a new experiment. Perform it and modify it if necessary to decant the air from the bag into a bottle filled with water. | Effective realization of an experimental approach.<br>The air can be decanted: it is matter. | Write down an experimental procedure. Write down an account of the experiment. |

# Lesson 1. What is in the bags hidden inside the boxes?

The pupils will attempt to distinguish materials by touch, based on their personal experience.

### Phase 1

The teacher has placed four plastic bags in boxes at the back of the classroom. These bags contain: 1) water; 2) sand; 3 ) air and 4) a small brick. He/she asks his/her pupils to handle the four bags without seeing them and to guess what is in each of them[2]. The pupils go to the back of the classroom in turn, handle the bags, describe what they feel and write this down in a document which will constitute their personal written record[3].


| | BAG 1 | BAG 2 | BAG 3 | BAG 4 |
|---|---|---|---|---|
| What did I feel? | *cold* | *soft* | *nothing* | *hard* |
| What is it? | *water* | *sand* | *air* | *stone* |
| My drawing | | | | |

*Figure 1*. Each pupil keeps a record of his/her activity.

### Phase 2

When all the pupils have taken their turn handling the bags, a collective discussion[4] guided by the teacher leads to a summary of what the pupils felt (work to objectivize what was felt) and a characterization of the content of bag 3 (air) referring to states of matter which the pupils already know: solid state, liquid state[5].

This phase causes the pupils a problem: the content of bag 3[6]. The discussion among the pupils centres on `Is it empty?', `Is it nothing?' (see the written record, above), or `Is it like the others but not the same?', `Lighter?'.

Validation, of course, takes place when the bags are opened. For bag 3, since nothing `comes out of the bag', the discussions become more than ever intense[7].

Following this discussion, a collective document is drawn up, under the scientific authority of the teacher[8], noting a number of characteristics which distinguish the two states of matter already

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[2]Video 1, lesson 1.

[3]Video 1, lesson 1.

[4]The questioning takes the form of work guided by the teacher. See the subsection `Basic structure of a module' in the section `Benchmarks for the teaching of a module' in the Introduction.

[5]Videos 2 and 3, lesson 1.

[6]Development of hypotheses and design of the investigation to be undertaken for validation/invalidation, oral formulation of hypotheses in groups, oral and/or written formulation of predictions by the pupils.

[7]Video 4, lesson 1.

[8]Acquisition and structuring of knowledge, comparison and relation to the results obtained in the various groups, confrontation with established knowledge.

known from the state of matter of the substance in bag 3 (the fact that it is impossible to flatten the bag completely means that `there is something there'). The pupils are then invited to suggest examples of other materials belonging to the three categories that have now emerged[9] . This phase forms part of the development and structuring of knowledge[10].

## Lesson 2. What do we know about air? Can you catch it?

The pupils are led to handle something called `air', and thus to consider it as a material.

**Phase 1**

The teacher asks a pupil to recall what happened in the previous lesson and invites the pupils to return to the questions about air[11] which the class had raised during the last lesson.

The aim of the debate is not to find immediate answers to all the pupils' questions (moreover, some of them are not appropriate at the elementary school level) but to make all the pupils aware of all the questions to which the subject might give rise:`What can we do with air?', `can we touch it?', `does it exist everywhere?', `are there places where there is none?'[12]

The discussion may relate to the presence or absence of air in the playground (`of course, it is there'), in the classroom (`naturally, for otherwise we would not be able to breathe'), in a cupboard (there is no longer unanimity on this, especially if the latter is half-open, `because then the air can escape')[13]. A collective written record, listing the various questions which have been raised, is gradually drawn up. After tidying up by the teacher, it will form part of the experimental notebook (see the written record, lesson 4).

At the end of this phase, the teacher invites the pupils `to catch some air' using plastic bags.

**Phase 2**

The pupils `fill' the bags in the playground, in the classroom, and also in the cupboard. The bags, once filled, are labelled by each pupil, who writes his/her name on them[14] together with the place where the bag was filled with air.

## Lesson 3. How can one prove that the bag contains something?

To demonstrate the presence of air is to prove that it exists.

**Phase 1**

The pupils are divided into small groups and the teacher asks them[15] to think of an experiment which would prove that the bag is not empty and that it contains something[16] .

The pupils begin by proposing experiments[17] which involve `emptying' the bag to demonstrate the presence of air.

These proposals for experiments are made on posters and/or in the experimental notebook before being presented to the class.

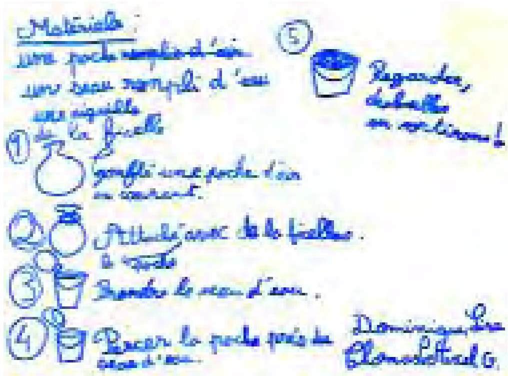

"*You make a hole in the bag and you feel* "

*Figure 2.* A proposal for an experiment which will not give the desired result.

[9]Video 5, lesson 1.
[10]Acquisition and structuring of knowledge.
[11]Choice of an initial situation, productive nature of the questioning to which the situation may lead.
[12]Formulation of the questioning, work guided by the teacher.
[13]Videos 1, 2 and 3, lesson 2.
[14]Video 5, lesson 2.
[15]Choice of an initial situation, productive nature of the questioning to which the situation may lead.
[16]Video 1, lesson 3.
[17]Development of hypotheses and design of the investigation to validate/invalidate them.


*"How do you show that there is air in the bag?*
*Hypothesis 1:*
*Pierce the bag which is inflated with air over a basin of water*
*Result of the experiment:*
*No air bubbles in the basin "*

*Figure 3.* Another procedure based on an erroneous conception of the material nature of the air.



*"Materials:*
*A bag [full of air]*
*A bucket full of water*
*A needle*
*String*
*1 Inflate a bag of air by running*
*2 Tie the bag with string*
*3 Take the bucket of water*
*4 Pierce the bag near the bucket of water*
*5 Look, bubbles come out !"*

*Figure 4.* A procedure which will be undertaken after discussion with the class.

**Phase 2.**

After the experiments have been undertaken, if the pupils decide that `it isn't working', the teacher manages the collective discussion to understand the reasons for these failures[18]. The pupils return to the idea that `air cannot be seen'. The teacher substitutes the expression `made evident' for `seen'. The concept is built up progressively, according to the everyday experiences of the pupils (in my bath, at the swimming pool....): bubbles should be made[19].

But it is not as simple as that. Although all the groups may very quickly agree on the need to use a basin with water, one still has to know how to proceed.

The idea that air would flow out of the bag towards the basin of water when the bag is pierced is often observed in children of this age, as can be seen in the accompanying extract from an experimental notebook.

**Phase 3.**

Since the solution found does not give the expected result, the pupils think of immersing the bag in water and puncturing it under the water to see the bubbles appear.

The performance of this experiment `which works'[20] by all the groups, leads to intense excitement among the pupils, real moments of euphoria[21], in which, after the setbacks and the disappointed hopes, all the pupils finally succeed in demonstrating those famous bubbles leaving the bag.

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[18] Investigation undertaken by the pupils.
[19] Video 2, lesson 3.
[20] Investigation undertaken by the pupils, reproducibility of the experiment (listing of the conditions of the experiment by the pupils).
[21] Video 1, lesson 3.

# Lesson 4. How can one recover the air from the bag?

Air, now considered as a material, will be handled in various ways.

**Phase 1.**

The initial situation, suggested by the teacher[22], involves asking the pupils to collect these air bubbles in a plastic bottle or any other chosen receptacle. Before embarking on the investigations in small groups, the teacher reminds the pupils of the main stages in the development of an experimental procedure (precise formulation of the question which one will seek to answer, hypotheses envisaged, materials needed, the experimental procedure proper). Such focussing on methodology will take place periodically during this module (nine lessons in the overall project), rigour in the investigative approach is only achieved progressively and these phases in which it is explicitly discussed are needed to enable everyone to acquire it at his/her own pace[23].

The teacher invites each group to draw up a procedure and discuss it amongst themselves[24], before putting it in writing on a poster[25]. This editing work, which is systematic in the approach adopted, serves a dual function: first, it encourages the group to reflect among themselves upon the of their phenomena involved and on the details of their experimental study[26]; ultimately, it enables the group to communicate the procedure it has designed to the class[27]. Each group works autonomously in this phase.

Of course, the pupils make orthographic errors. However, unless requested by the pupil, the teacher does not become involved in this phase. A choice was made to leave them with a free reign in this phase so that they can all concentrate on the imagination and creativity needed to construct the procedure. These errors are corrected during the collective editing of the written institutional record which will appear in the experimental notebook with a distinctive symbol (for example, a green circle), enabling the pupils to distinguish between that which has been approved by the teacher (correct in terms of knowledge and orthography) and that which is the result of the personal work of the small group (see the examples of written records and also of pupils' notebooks). See the paragraph `Science and language in the class' in the Introduction for the management of written material produced in class.

We must emphasize the maturity acquired by the pupils in this area when what is required has been clearly explained to them. The pupils know that in this phase of their work, they have a certain amount of freedom as far as orthography is concerned, although they must not neglect it as such[28]. They ask themselves questions (how do you spell such and such a word?) since they know that there are rules, but encounter no `mental blockages' in drawing up a document which will be presented to everyone, since they need not fear being reprimanded by the teacher.

This choice of teaching technique was explained to the pupils and to their parents at the start of the cycle, for example, in a letter to the parents.

*"My experiment:*
*We took a bag and a bottle and made a hole in the bag with scissors and then took the bottle so that the air didn't come out. The air escapes from the bag making bubbles, but cannot get into the bottle"*

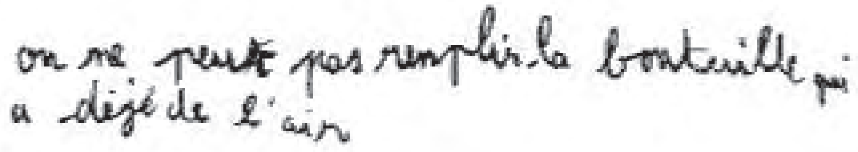
*Figure 5*. A first experiment which will fail.

[22] Choice of an initial situation, productive nature of the questioning to which the situation may lead.
[23] Investigation undertaken by the pupils, moments of internal debates among the group of pupils: the ways in which experiments are implemented, control of the variation of parameters.
[24] Video 2, lesson 4.
[25] Video 3, lesson 4.
[26] Investigation undertaken by the pupils, reproducibility of the experiment (listing of the conditions of the experiment by the pupils).
[27] Acquisition and structuring of knowledge, comparison and relation to the results obtained in the various groups.
[28] Video 3, lesson 4; video 1, lesson 3.

**Phase 2**

The teacher asks each group to present its procedure to the class and then to undertake the experiment in front of everyone (possibly after having tested the material). If it fails, the experiment is then subjected to critical discussion in order to try to understand the reasons for this[29]. A fresh attempt is then made, taking into account the above considerations.

Some examples of pupils' proposals:
- Among the exotic and unexpected proposals, one group suggests that, in class, the bubbles released should be collected with a spoon and then decanted `very delicately' into the bottle[30]. Unfortunately, the experiment is a failure, but the pupils persist, convinced that if the air bubbles burst when the spoon comes out of the water it is because the operator is not skillful enough. However, faced with continued failures, despite changes of operator, one has to give way to the evidence: the problem lies elsewhere. The ensuing discussion ends when a pupil ultimately says `you can't see air bubbles in the air'.
- Another group suggests using a tube to connect the bag of air to another `empty' (that is to say, flattened) bag and then pressing on the inflated bag with one's hands. Success is immediate: the flattened bag inflates while the other is emptied of its air. On the other hand, those who connect the two bags directly cannot succeed: if they don't tie them together with string at the junction the air escapes; if they tie them together the air can no longer pass.
- Most groups suggest attaching the bag to a bottle... but the air bubbles cannot penetrate into the bottle. This would also need several inconclusive trials before they realize that:




[it is impossible to fill the bottle which already has air in it]

**Phase 3**

Even once the bottle is full of water, the pupils do not necessarily succeed. In fact, the idea of `pouring the air' into the bottle by placing the bag over it may also emerge again. The discussion centres on the fact of knowing whether or not the bottle must be full to the brim with water. One argument is that if the bottle is not full of water `that will never make bubbles[31]. Numerous trials will be required before the pupils, seeing that `it isn't working', have the idea of turning the arrangement upside down. There is then a moment of intense satisfaction when the first bubbles rise into the bottle of water placed over the bag.

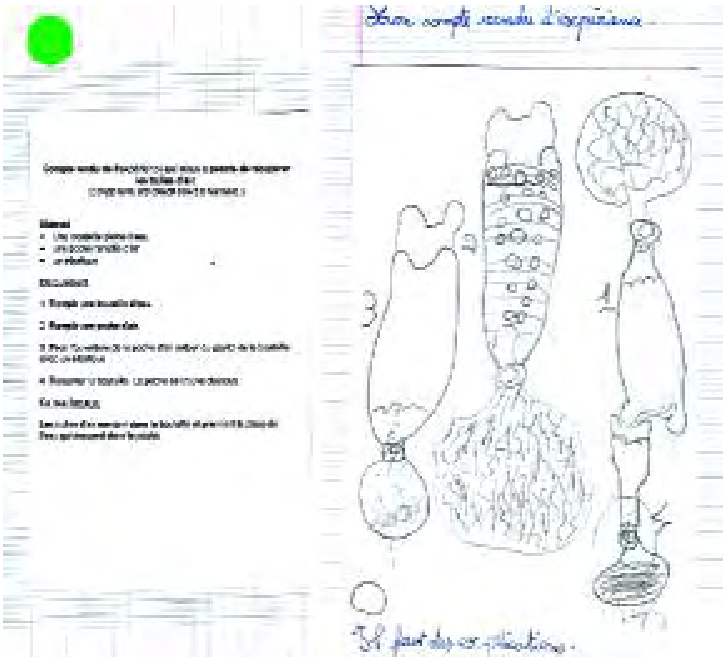
*"My account of the experiment:*
*1Put water in a bottle with a bag, put air inside and put the end in the bottle.*
*2. The bottle is turned over"*

*Figure 6.* An experiment which learns the lesson from previous failures.

[29]Video 4, lesson 4.
[30]Video 5, lesson 4.
[31]Video 6, sequence 4.

The teacher's role is to explain the passage of the air into the bottle and of the water into the bag (and vice versa).
Each group will then implement this correct procedure[32]. A collective record will then be drawn up in common and placed in the experimental notebook (the green circle indicates that this is a collective document, drawn up under the scientific authority of the teacher).

*"Account of the experiment in which we were able to recover air bubbles. (Collective oral account dictated to the teacher)*
*Materials:*
*A bottle full of water*
*A bag full of air*
*An elastic band*
*Procedure:*
*1 Fill a bottle with water*
*2 Fill a bag with air*
*3 Attach the opening of the bag of air around the neck of the bottle with an elastic band*
*4 Turn the bottle over. The bag is underneath*
*What we saw:*
*The air bubbles rise into the bottle and take the place of the water which goes down into the bag."*



*"My account of the experiment: Needs explanations"*
*Figure 7.* The collective record drawn up with the teacher (green circle).

**Phase 4**
After these four lessons, one can make a first assessment of what has been discovered about air: you can catch it; you can fill a receptacle with it; you can decant (cause it to pass from one receptacle to another). This leads to a first step towards the characterization of a third state of matter, gases, of which air is a representative.

## Conditions for the teaching of the module

### Sensible duration
This type of work cannot be carried out to a punctilious timescale; it is only fully meaningful if it is carried out over a long period, which means that the framework of a module is justified. The four lessons described in this document form part of a module taught in the classes which took part in the project. The entire work can be found on the CD ROM, *La materialité de l'air*, mentioned in the bibliography at the end of this chapter.

### Materials
The materials used for these four lessons present no particular problems: plastic bags, basin of water, plastic bottles...

### Recommended fact sheet
Sheet no. 3, `Air'.

[32]Videos 8 and 9, lesson 4.

## Conclusion

This module has two main objectives, one objective relating to the knowledge to be acquired in connection with the programme of cycle 2 and another one relating to the experimental approach and to autonomy. The experimental demonstration of the presence of air in the bag by the pupils is not as easy to achieve as they imagine at the outset: to show that the bag contains something it suffices to pierce it so that it empties itself.

Many pupils can only gain an awareness of the problem (the air does not fall into the water when the bag is opened over the basin of water) after having attempted the experiment. In this approach, the pupil learns from an experiment which `does not work' (provided that the reasons for this failure are analysed collectively). In the case of recovery of the air in a bottle, the pupils very quickly think of using a bottle and then of filling it with water (to see the bubbles). The pupils place the bag of air above the bottle and do not understand why the bubbles do not go down into the bottle. When they do finally think of turning the arrangement upside down (bag of air below the bottle of water), it is during the action, that is to say, while thinking with their hands. *A priori*, they don't think of placing the bottle of water on top because they think that the water will fall and thus that the experiment will fail.

It is interesting to note that this experiment is very rarely carried out in class. The experiment which is proposed for pupils in almost all school handbooks involves placing the full bottle of water immediately on top, with the bag of air below as though it is the only possibility.

During this module the pupils have carried out operations on air which they are used to carrying out on other materials (catching it, transporting it, retaining it, decanting it). They have not all yet built up the idea of the material nature of air; this will require other lessons in which air will be used to fill balloons and bottles, such that when escaping from these the air will set other objects in movement. This concept of the material nature of the air can only be built up over time and through a diversity of situations. Other situations must be presented in which the pupils will be led to feel the wind[33], and to wonder about the fact that the air has a mass (in cycle 3) and about the fact that its presence is necessary for living beings (desirable openings on to other cycles and on to living things).

## Taking things further

The work on air which has just been described here is not exhaustive, other activities on air must be undertaken in connection with other points of the programme of both cycle 2 and cycle 3. Moreover, during the debate on air (lesson 2) the pupils showed some concern about these elements[34].

## Bibliography


### Websites

The websites listed below include educational and/or scientific documentation for teachers on the subject of air:

- French national website for *La main à la pâte:* www.inrp.fr/lamap/activites/air/accueil.htm
- Desco website: www.eduscol.fr/D0048/r_prim.htm
- website for the Côtes d'Armor: www.lamap22.fr.st
- website for the Dordogne: http://eds24.free.fr/PAGES/MATIERE/EVIDAIR/SoMod.htm
- website for the Pyrénées-Orientales: www.ac-montpellier.fr/cd66/map66/pages/activites_scientifiques/air/cadre_air.htm
- website for the Haute-Savoie http://iufm74.edres74.ac-grenoble.fr/travaux/tphysique/air3c.htm
- website for the Savoie: www.ac-grenoble.fr/savoie/Disciplines/Sciences/Index.htm
- website for the Seine-Saint-Denis: http://lamap93.free.fr/preparer/gg/gg-00-01ind.htm

### CD ROM

- *La materialité de l'air* in cycles 2 and 3, CRDP, Bordeaux


[33]See the module `How do we know where the wind comes from?'

[34]Videos 1, 2 and 3, lesson 2.

# A seed, a plant ?

cycle 2

This module is designed to extend and refine the pupils' reflection upon living things, which began in the nursery school, and to help them to find, progressively, the evidence which will enable them to recognize life. More generally, this module is used to build up the notion of the seed, progressively, by means of educational activities. The seed (its definition and role) and germination are presented as stages in cycle 2, the development cycle will only be introduced as a concept in cycle 3. These lessons permit the development of an investigative scientific approach; they are easy to teach and do not require the purchase of any specific and/or expensive materials.

The study of the seed and its importance, as such, at the very start of plant development (for flowering plants and conifers), is particularly appropriate in the primary school, since it is accessible to the pupils. Gardening activities, starting with sowing, are frequent in the nursery school and, in general, children have an intuitive knowledge of the notion of the seed and of its primordial role (product of reproduction and means of dispersion).

## Position in the programmes

- In cycle 2: the notion of the seed is built up. The seed can be defined as follows: a dehydrated living plant, made up of an embryo in an inactive state of life, surrounded by food reserves and protected by a coat. The pupil will thus be led to wonder about the conditions needed for a return to active life which will end in the development of an adult plant.

| Extracts from the programme | Extracts from the application document |
|---|---|
| **From familiar surroundings to distant horizons**<br>Skills to be acquired by the end of the cycle:<br>- to be able to pick out the elements studied on photographs taken from different viewpoints, and on plans;<br>- to have understood and retained certain aspects of the diversity of forms of vegetation, of animal life and of habitats. | |
| **The passage of time**<br>Skills to be acquired by the end of the cycle:<br>- ability to create and use various types of calendar and to locate the events studied on these. | |
| **The living world**<br>- manifestations of life in animals and plants.<br>Skills to be acquired by the end of the cycle:<br>- to be able to observe, identify and describe certain characteristics of animal and plant life;<br>- to have understood and retained what distinguishes that which is alive from that which is not alive, with reference to the major functions of living things and to the manifestations of animal and plant life. | - Bring some plants into the classroom and the school and look after them<br>- Study the characteristics of objects or living things, in order to distinguish between the animal, vegetable and mineral worlds and to categorize them. |

- In cycle 3: the origin of the seed will be presented, showing the transformations in the development cycle for flowering plants (from the flower to the fruit). During this cycle an experimental approach can be taken further by studying the simultaneous influence of a number of germination factors.

| Extracts from the programme | Extracts from the application document |
|---|---|
| Unity and diversity of the living world:<br>- stages of development of a living thing;<br>- conditions for the development of plants<br>- the various modes of reproduction (animal and plant): procreation and asexual reproduction. | |

- At Collège (form 6): experimentation is proposed to prove hypotheses about the germination conditions for seeds; this leads to reflection on the influence of climatic conditions (at most two) and on the germination of seeds in their surroundings. pupils are reminded that the seed comes from the flower and that it is then studied as a form of dispersion which enables flowering plants and conifers to populate habitats.
- At the Lycée: the pupils will take an interest in plant morphogenesis; the morphology of a plant depends on the genetic characteristics of the species to which it belongs and also on its environment.

### Knowledge and know-how to be acquired by the end of the module

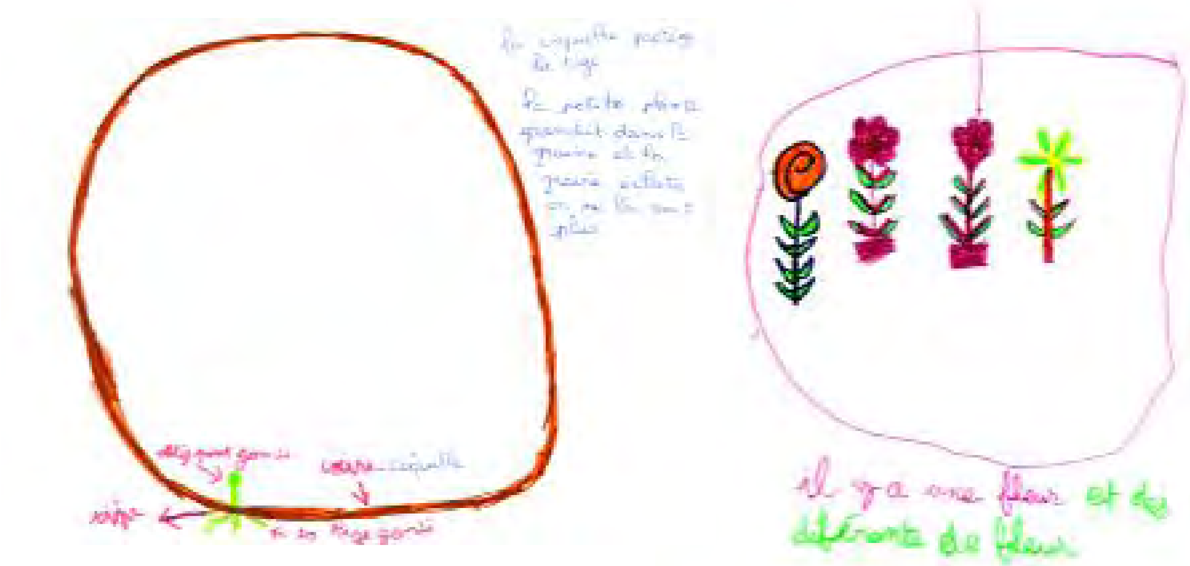
- To distinguish between what is alive and what is not alive via an example of a plant form known to all: the seed
- To acquire the notion of the seed.
- To design and undertake an experimental procedure.

## One possible way in which the module might be taught

| Lessons | Initial question | Activities undertaken with the pupils | Scientific approach | Linguistic activities |
|---|---|---|---|---|
| Lesson 1<br>Lesson 2<br>Lesson 3<br>Lesson 4 | A seed or not a seed? | Initial conceptions. Preparation for a possible outing.<br>Collection of samples.<br>Sorting and formulation of hypotheses.<br>Planting of seed trays | Observation and experimentation. | Oral communication. Individual writing and drawings<br>Collective writing |
| Lesson 5 | | Observation and interpretation | | |
| Lesson 6<br>Lesson 7 | What is inside a seed? | Initial conceptions<br>Observation, interpretation, discrimination of the samples | Observation under a magnifying glass and dissection | Oral communication<br>Individual drawings |
| Lesson 8<br>Lesson 9<br>Lesson 10 | What does a seed need to germinate? | Initial conceptions<br>Hypotheses<br>Experimental procedure<br>Analysis of results and conclusion | Experimentation | Oral communication<br>Individual writing and drawings.<br>Collective writing. |
| Lesson 11<br>Lesson 12<br>Lesson 13 | How do seeds germinate? | Elaboration of the experimental procedure, observation<br>Collective activities centred around the social importance of the seed. | Continuous observation and documentary research. | Individual writing.<br>Oral communication.<br>Collective writing.<br>Reading |
| Lesson 14 | Extension: do seeds travel? | Collective activities centred around the biological role of the seed. | Observations and documentary research. | Oral communication.<br>Reading. |
| N.B. - Between lessons 4 and 5 and lessons 11 and 12, a period of continuous observation will be needed to follow developments in the seed trays. The linguistic activities (see picture) may be carried out with the class, in small groups, or individually. | | | | |

## Lesson 1. A seed or not a seed? - initial conceptions

The pupils seek to determine what a seed is.
This lesson can be integrated with lesson 2, depending on the time given over to each science lesson.
The teacher may choose one of two alternatives: organize a nature outing, during which the pupils will collect samples; or offer a set of samples which he/she has prepared in advance.
The lesson may begin with each pupil being asked to draw one or more or the seeds, as he/she sees them  and to explain what a seed means to him/her.
To build up their experimental notebooks, the pupils are asked to write down their idea of what seeds are (text, drawing...).



*"[left:] The shell protects the stem.*
*The small plant grows in the seed and the seed bursts and can't be seen any more.*
*[caption: stem - stem can grow - outline of shell - grown stem ]*
*[right:] There is a flower and different flowers."*
Figure 1. The pupils present their idea of what seeds are.

## Lesson 2. A seed or not a seed? - collection of the experimental material

During a nature outing, the pupils take samples of what they think are seeds.
The starting point for the module may be an outing, undertaken after the month of September[1].

**Collectively**
The teacher asks the children to collect what they think are seeds and, in order to establish a link between the samples collected and their origin, suggests that the pupils should carefully note the place where they collected the sample (under or  on a tree or a plant, on the ground, under leaves...)

For classes in heavily built-up regions,  which could not undertake this collection, one alternative may be for the teacher to prepare several sets of seeds and various other samples beforehand, which

[1]At this time, clothes and shoe laces become covered with seeds and pips  as soon as one gets on to  a modest area of waste ground. The teacher will be able to collect the samples which will be of interest in lesson 14.

will dispense with the need for an outing. Since the experimental material is known in advance, the teacher can be almost certain that the seeds are viable and the experimentation will be more satisfactory.
After the collection, the class has a large and varied selection of samples.

*Figure 2*. Examples of small samples (seeds, tea, pebbles).
The coin (here, 10 euro cents) gives an idea of the scale.

## Lesson 3. A seed or not a seed? - sorting of the material and formulation of hypotheses

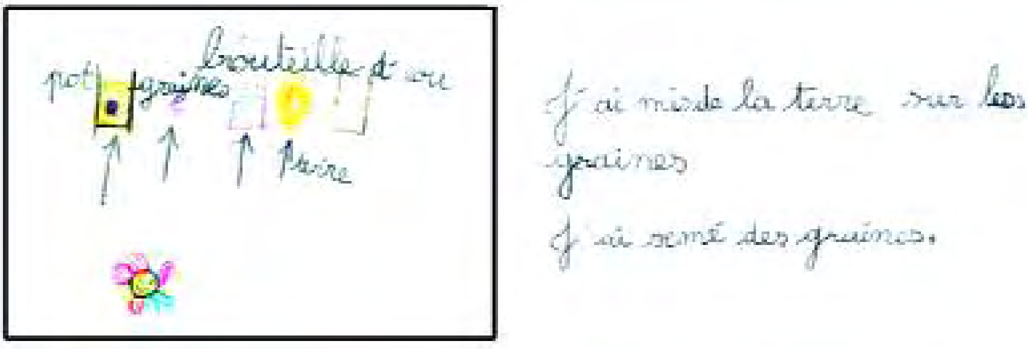
A number of samples are available to the pupils who now think about how to recognize the seeds among them and carry out the sorting.
In order to be certain that the set of samples to be studied includes both `seed' and `non-seed' samples, the teacher may either assemble together the samples from the collection and redistribute them to the groups of pupils[2], or suggest that the pupils in a group should share their collections.

### In small groups

The teacher presents the various samples (seeds and non-seeds) to the pupils, without saying whether or not they are seeds. He/she asks the whole class: `what is this?' or `which of these elements do you think are seeds?'. After this reflection in small groups, which ends with a first sorting of the samples, it is quite likely that not all will agree about whether or not a particular sample is to be considered as a seed.

### Collectively

In order to engage the pupils in more advanced reasoning, the teacher asks: `how can we check whether these are pebbles, ... , or seeds?'. A consensus may rapidly be reached: `we need to sow them to find out'. The teacher becomes engaged in a collective oral exchange with a view to leading the pupils to formulate their forecasts of the result.




*"[ pot - seeds - bottle of water - dish] I put soil on the seeds I sowed seeds."*
*Figure 3*. `We need to sow them to find out'.

[2]Depending on the nature of the collection, the teacher may at this point in troduce additional samples of `viable seeds' and/or `non-seeds', chosen for their potential interest in this module and in order to improve the result. Here, it is advisable to avoid introducing samples which are unlikely to be found in nature (grains of semolina, vermiculite).

Several questions are used to help the pupils with this reasoning: `What might happen if we plant all these?' The debate leads to the following early question: `If it grows, does that mean that these are seeds[3]?'

The pupils simplify the experimental procedure and note the anticipated result, giving their reasons.

## Lesson 4. A seed or not a seed? - experimentation on the seed trays

The pupils organize their planting and set up their seed trays.

### In small groups

A group of two to four pupils may take charge of a seed tray, comprising, for example, two samples on the workbench. The pupils mark out two sectors in a polystyrene trough filled with a damp mixture of garden soil and sand.

For each sector, the pupils plant the samples, which they space out and count. Each sector is identified by a small flag (wooden or wire marker with label) on which one can note the number of elements sown in that sector.

The teacher may suggest the idea or use of a calendar on which the pupils will be able to stick a sample identical to that from the sector, on the appropriate day, when a first shoot has been spotted.


*"Our seed beds:*
*We planted seeds randomly*
*The class goes outside and we observe our seed beds.*
*Observations of 23 March 2001*
*Some soya and marrow seeds have come through*
*Leaves appear on the stems of ginko biloba"*

*Figure 4*. Examples of seed beds created by the pupils.

In cycle 2 it is difficult to distinguish between a seed and a fruit containing a seed, such as a sycamore key. The distinction will be made in cycle 3 after a study of the seed. To dispel all ambiguity, in cycle 2, we shall deal only with the systematic observation of `actual seeds' when studying germination.

[3]There are several possible solutions for the sowing: in soil proper, building of a propagator (technological object) , a trough designed earlier by the teacher, a trough purchased from a supplier of educational equipment.

## Lesson 5. A seed or not a seed ? - observation of the seed trays, interpretation

The pupils undertake continuous observation of the seed trays and draw the first conclusions. They recognize a seed because it can change: it grows when you place it in earth; a seed which grows produces a plant; two seeds which look alike produce two shoots which look alike.

### Individually

Over approximately a quarter of an hour's activity (observation and written records) every other day for a week to 10 days, depending on the importance of developments in the seed trays, the pupils observe the changes: this amounts to continuous observation. Each time, each pupil draws and writes down what he/she sees, noting the date. After each observation, pupils who so desire report what they have noticed to the class.
As time passes by, differences appear in the developments in the seed trays: young plants emerge from the ground from the third day onwards, others only come up at the end of the seventh day. For some seed trays, no plants appear. The pupils suggest `taking away the soil' to better observe what they put there. They determine what has changed.

### Collectively

Approximately four to five days after the seed trays have been set up, a first inventory can be made, noting:
- what has not grown[4] ;
- what has grown.

The pupils note that, for a given sector, the young shoots appeared almost all at the same time, and that there are differences between the sectors (sometimes of several days). In a single sector all the shoots look alike, just like the seeds that were sown, and there are as many shoots as seeds, or sometimes fewer (if a seed has not developed), but never more.

### Collective summary

The teacher invites the pupils to read their written records again to refresh their memories about the initial situation, the questions and the forecast. The pupils try to explain what the experiment has shown, with reference to the initial questions. Each group then presents its explanation to the class. The teacher suggests a debate, which will lead to the generation of an appropriate phrase. For example, a phrase such as `Plants have grown. That means that they were seeds' will be generated by the group/class and approved by the teacher. One can recognize a seed from the fact that it can change[5].
Everyone writes down the conclusion reached at the end of the debate.
These first observations form the basis for a new question concerning the criteria for distinguishing a seed.

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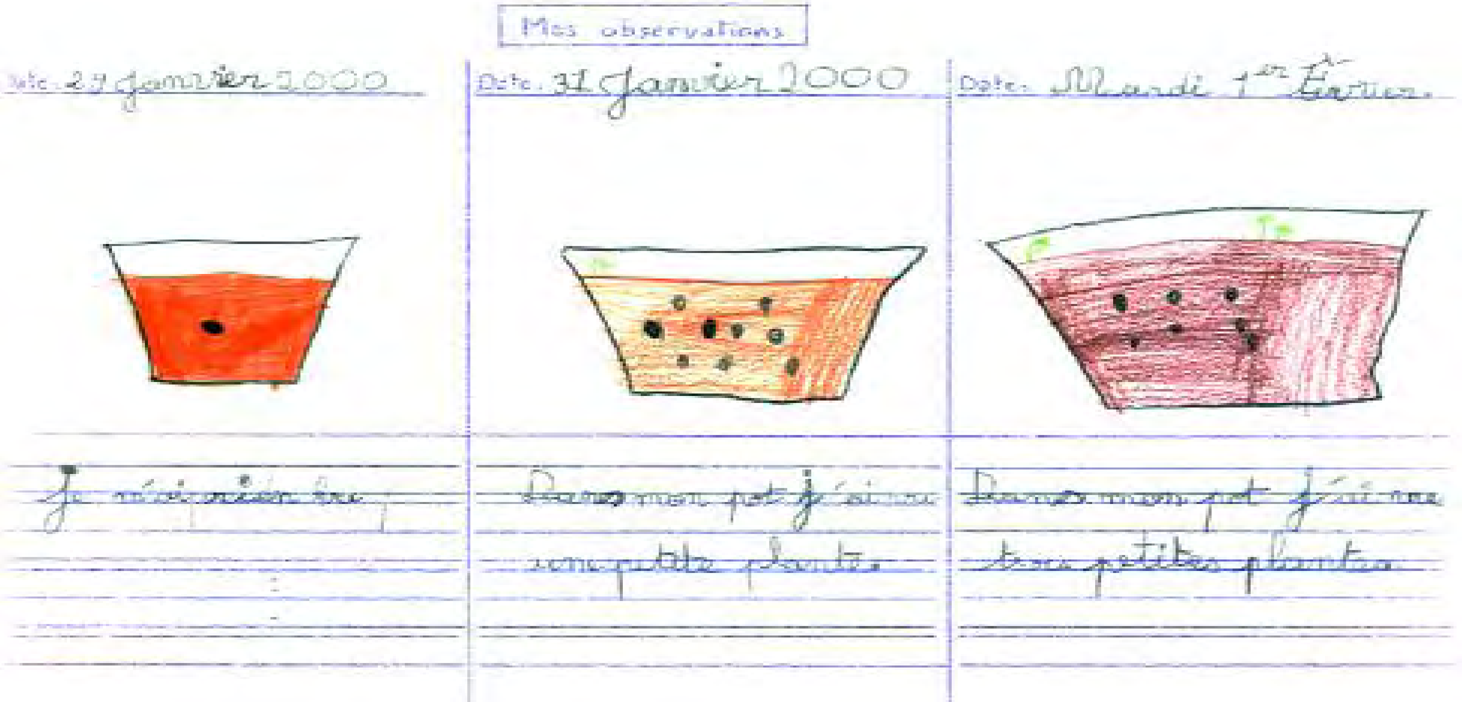
[4]The sectors in which nothing has grown may represent not only sectors in which none of the elements planted were seeds, but also sectors of non-viable seeds or seeds for which the germination conditions were not favourable: the initial hypothesis that `if these are seeds they will grow...' appears to be confirmed, but is not sufficient: other criteria for discrimination need to be found...

[5]This ability to change over time and to interact with the environment are signs that can be used to detect living things. The concept of a living thing can only be built up very progressively through numerous other activities.




*My observations*:

| | | |
|---|---|---|
| *Date: January 29th 2000* | *Date: January 31st 2000* | *Date: Tuesday February 1st* |
| *I saw nothing* | *I saw a little plant in my pot* | *I saw 3 little plants in my pot* |


*My observations* :

| | | |
|---|---|---|
| *Date: Friday February 4th* | *Date: Monday February 7th* | *Date: Monday February 14th* |
| *There are plants* | *I saw 19 plants in my pot* | |

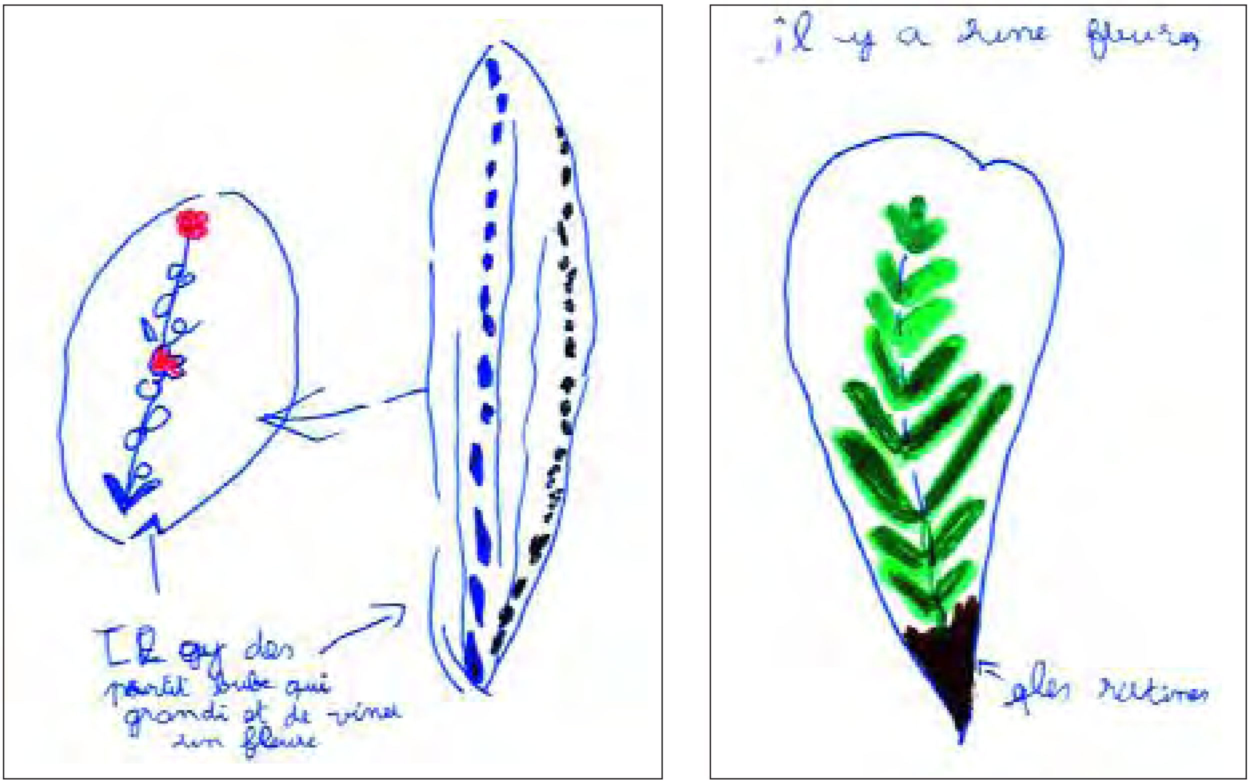
*Figure 5*. The pupils observe and record the developments in the seed trays in their experimental notebooks.

## Lesson 6. What is inside a seed? - initial conceptions

After having distinguished morphological (relating to external appearance) and ontogenetic (relating to stages in the development of the seed) characteristics, the pupils are interested in visible anatomical criteria (internal disappearance of the different parts of the seed).
In order to distinguish new criteria, the children become interested in what is inside the seed. They apply their thoughts to the internal organization of the seed.

### Collectively

By formulating questions stemming from their observations and difficulties arising from the previous lessons, the teacher will collect together the pupils' initial conceptions:
- how to separate `non-seed' elements from `viable seed' elements?
- how to explain this relationship between a seed and a plant?
- how (and by what means) does a seed grow?



*"There are parts which grow and become a flower. There is a flower. The roots"*
*Figure 6.* Two examples of initial representations of what is inside a seed.

Suggestions, probably formulated orally, will include `we need to look inside the seeds...', `there is a small plant inside the seed...'. The pupils may be asked to draw what they imagine there is inside a seed before it is sown and to say what happens when it germinates.
Some of the pupils' work on this can be analysed and compared collectively[6]. To compare the reality with the conceptions and to answer the earlier questions, it is decided, by mutual agreement, to observe the inside of a seed. For the observation and the comparison to make sense, an `actual seed' sample should be compared with the other samples (including `non-seeds' and `non-viable seeds). The choice of the `actual seed' sample is therefore of paramount importance[7].

[6]Some drawings show both a seed and a mature plant with no relationship between the two: the idea of the transformation of the seed is not yet present. Moreover, some pupils may draw a miniature adult plant rather than a seedling with the seed; thus, the idea of an embryo which is transformed also needs to be built up.
[7]Depending on the preceding experimentation, the reference element should be a sample which has germinated and which (partially) confirms the hypothesis. Thus, with this lesson in mind, the teacher will have carefully retained non-germinated examples from these samples.

The reference sample is chosen to be easily observable and should, for preference, be a large seed, such as a pea, a bean, a lentil or a broad bean, which opens easily into two parts. It is easier to suggest, in the first instance, that the whole class should observe the same seed.

## Lesson 7. What is inside a seed ? - anatomy of the seed

The pupils dissect and observe the interior of various seeds using a magnifying instrument; they discover there and draw the various seed organs: the embryo, the food reserves and the protective coat. They make a definitive distinction between `seed' and `non-seed' elements in the collection.
The seed chosen as a reference may be dissected by the teacher, in order to demonstrate to the pupils the technique to be used, which may prove to be delicate because of the size of the seed. The samples to be compared have been set to soak overnight on the previous evening so as to soften the integuments and to make it easier for the pupils to open the seeds.

### Individually

After dissecting their seed, the pupils have a short time for observation on their own. Depending on the equipment available, the pupils may, in the first instance, undertake observation with the naked eye, and then use a magnifying instrument (binocular magnifying glasses, hand-held magnifying glass).
Simultaneously with their observation, they are asked to do a drawing to compare their initial conceptions with what they see.

### Collective summary

A phase of collective debate leads to a structured and annotated individual drawing. This drawing might mention the embryo with its two small white embryonic leaves[8] (which can be referred to by the term cotyledons or first leaves) which are clearly visible on the bean seed (the two internal halves of the seed), and the `skin' or coat (or integument).

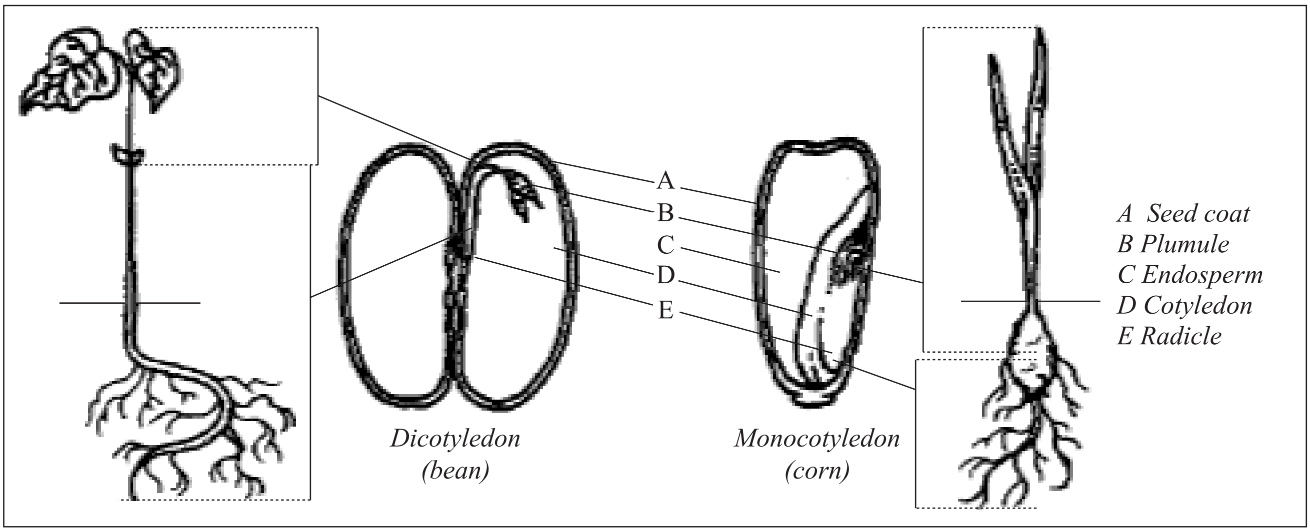



*Figure 7.* Anatomical structure of the seeds of flowering plants.
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[8]In legumes (beans, peas, lentils, etc.), dicotyledenous plants (embryo with two cotyledons), the two embryonic leaves become smaller and smaller (the food reserves which they constitute are progressively used up) and eventually disappear completely when the seedling develops. In maize and the graminae (wheat, lawn seed, etc...), monocotyledenous plants (embryo with one cotyledon), one of the two cotyledons does not develop and only a single embryonic leaf is seen to emerge from the seed; the other serves as a food-reserve organ, and remains in or on the substrate.

**Individually**
With a view to generalization, the pupils individually observe other seeds in order to identify the same component parts. From then onwards, the pupils no longer observe the same seed at the same time; it is necessary to distinguish between the observations and then generalize.

In lesson 2, the samples which did not grow (but which were carefully retained) probably did not contain embryos. This can be checked by crushing (if that is possible) the small grains of a mineral nature: they go to dust and there is no embryo; what is more, there is no coat (integument) around the grain.

Identical observations are made with grains of an organic nature, which are not living things. One then sees that some samples, comparable to seeds, which have not grown, are decomposing (they give off a foul odour when opened). These seeds are therefore `non-viable' (not ripe) or dead (because of the germination conditions).

## Lesson 8. What does a seed need to germinate ? – initial conceptions

Now that the notion of a seed has been made clear from a morphological, ontogenic and anatomical point of view, it seems of interest to wonder about the physiological needs of this living thing, that is to say about the `environmental conditions[9]' necessary for its development.

The children seek to determine what the seed needs for it to germinate successfully. Observation of the differences in the developments in the seed trays (see lesson 5, phase 1) leads the pupils to formulate the question: `What make certain seeds grow more quickly than others?'

**Individually**
First, the teacher asks each pupil to write down what he/she thinks the needs of the seed are. For the most part, the pupils use the formulation `Perhaps...'. Over the class group as a whole, some pupils have only one idea, while others have several.

**Collectively**
Second, the pupils' ideas are put together in common and become `the ideas of the class[10]'. Here is a sample of what the pupils may suggest:
- `Perhaps they shouldn’t be planted too deeply?'
- `Perhaps they should be put in the light?'
- `Perhaps they shouldn't have too much water?'
- `Perhaps they aren't the same plants?'
- `Perhaps they shouldn't be in cold air?'
- `Perhaps they shouldn't be pressed on too heavily?
Everyone writes down the ideas of the class.

After the questions formulated by the pupils, the teacher picks one and sends it back to the class group. In this module, the question chosen is `Perhaps they shouldn't have too much water?'. The lessons which follow centre on this choice, but can be adapted to other environmental factors.

[9]In cycle 2, one will choose to deal with just one or two growth factors (water, nutriments). More comprehensive work on plant growth may be undertaken in cycle 3.
[10]The choice of a question may be motivated by various reasons:
- the feasibility of the corresponding experiment from the physical point of view and its safety;
- the concept which it will be possible to build up, in connection with the programmes (cycle 2, cycle 3);
- the methodological skills which will be required.

## Lesson 9. What does the seed need to germinate ? – experimentation

The children set up an experimental procedure to determine whether water is a necessary factor for germination.
The chosen question is: `Perhaps they shouldn't have too much water?'. A debate begins and the discussion turns around the expression `not too much water'. Some pupils suggest that `not too much water' does not mean `a great deal'. We don't know how much `not too much water' is! The exchange continues and an idea is put forward: `We shouldn't talk about water, but about some water'.

The initial questions become: `Does the seed grow or not when it is given some water?' and `Does the grain grow or not when it is not given any water?'. These questions will allow the pupils to work on the germination conditions for seeds and also to establish a methodological skill, the setting up of an experiment and of a counter-experiment in order to be able to compare the results and assert the conclusions.

It is preferable to choose two or three different types of seed as experimental material. This allows one to note that the requirements for germination are common to all seeds. Some seeds (bean, wheat, pea, ... ) can be chosen as `reference seeds' (see lesson 2, phase 2) and permit and optimization of the experimental success.

**In small groups**
A suitable propagator for this experiment is chosen (in which the dry seed trays can be kept separate) where the pupils will sow different types of seeds in watered and dry sectors, noting the type of seed, the date, the time and whether the seeds are watered on the small label[11].
The children sketch the experimental procedure in their experimental notebooks, not forgetting to explain and label their drawings.


*"This is the experiment of my group on March 7th 2000*
*I put water in: water is put in, a plant should grow;*
*I did not put water in: no water is put in, nothing should grow"*

*Figure 8.* Example of a schematic representation explaining the experimental procedure set up by the class.

[11]It is important to ensure that the watered sectors of seeds do not suffer from evaporation. One can either install an element to limit the evaporation, or top up with water to a level which will be regularly monitored.

# Lesson 10. What does the seed need to germinate ? - conclusion

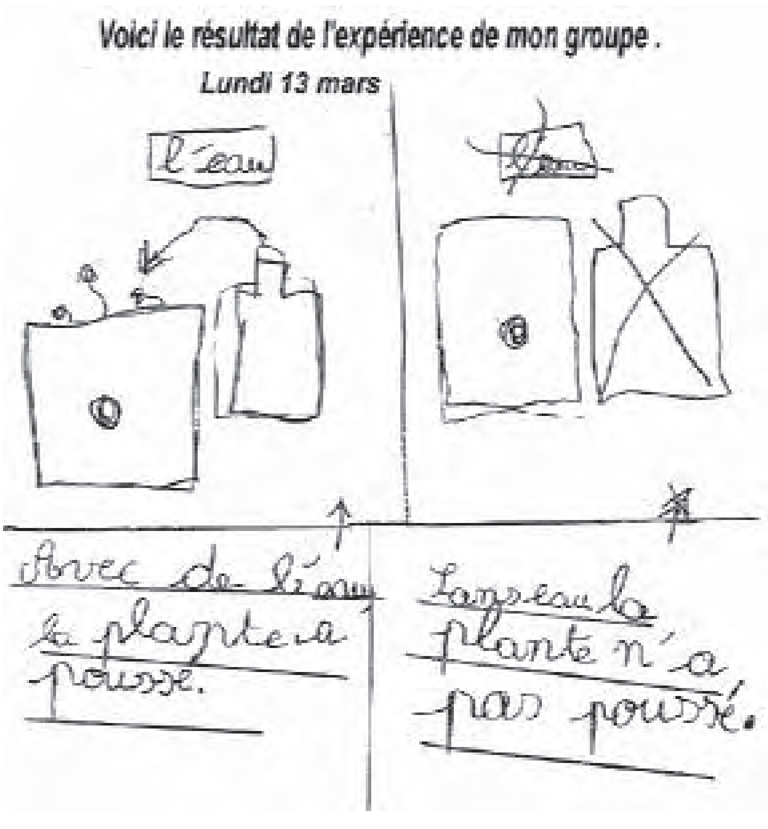
The pupils make inferences from the results they have obtained from their experimentation and write down their conclusions; a seed needs water to germinate; without water it does not germinate. The teacher invites the children to analyse the results of the experimentation.

### Collectively

After several days, one can see that the seeds have not germinated in the sectors in which there was no water. Conversely, in the watered sectors, shoots have appeared. One or two small green `leaves' have appeared. The cotyledon(s), together with a small white root system have also appeared.
One can then compare the sectors in which seeds of the same type were sown; the pupils note that the seedlings look similar and that different seeds produce seedlings which are quite different.

### Individually

Each pupil writes down the results from his/her group's experimentation in his/her experimental notebook together with the conclusions of the class group.
This experiment can be extended to water as a necessary factor for plant growth[12].




*"Here is the result of the experiment of my group on Monday March 13$^{th}$*
*[left:] With water the plant has grown.*
*[right:] Without water the plant did not grow."*

*Figure 9*. Example of a schematic representation showing the results of the experimentation

[12]Several experimental approaches are possible. Here are two examples:
- allow growth to continue but do not add water. The water level will fall (see the previous footnote) as a protection against evaporation, then the seedling will perish when the water level is at its lowest. The seedling needs water to develop (and not only for the seed to germinate);
- soak the seeds overnight in a glass of water and then distribute them across the unwatered sectors; take observations on the following day. `Something' will be seen coming out of the seed (the radicle). If no water is added, the seed will not develop further and will eventually die. If water is then added, it will not start up again.

## Lesson 11. How do seeds germinate ? – experimentation

In this stage, germination will be defined as the first stage in the development of a new plant from the seed. This notion will be picked up again in cycle 3 during the study of the stages in the development of a flowering, annual or perennial plant. At the end of the module, the pupils will have observed a biological transformation and written about the different stages in the evolution of a living thing. By way of a first extension, a parallel could be drawn between the evolution of the human diet and the evolution of science and technology.
Using the seed trays, the pupils seek to learn how the seed `wakes up' and how it becomes a seedling.

### Collectively

Seed trays are again set up to see how the seed embryo is transformed into a plant. The pupils know that plants need water to germinate and that they find this water in the soil which is kept moist, but `the soil is in our way for the observations'. What means can be used to eliminate this obstacle presented by the soil?
It is left to the pupils to suggest other ways in which the seeds can remain in moist surroundings and at the same time be observed. The teacher may help the pupils in this research: sowing on cotton wool (with the risk that what is being grown may rot); on filter paper, blotting paper or, better still, on polystyrene blocks pierced with holes (one for each seed) and floating on the surface of water in a trough.
During this first phase the teacher may also set under way, with the pupils, the written records[13] of the continuous observation which is about to be undertaken.

### Individually or in small groups

Continuous observation for about 15 minutes (observation and written records) may be suggested, depending on the importance of developments in the seed trays, every other day for a week to 10 days.

## Lesson 12. How do seeds germinate ? – exploitation of the data

The children discover that the organs which they have observed in the seed all have a well-defined role: the root develops first, it grows downwards; the leafed stem then develops upwards; the two halves of the seed simultaneously serve as `first leaves' and a `food-reserve' organ when the seedling emerges.

### Individually or in small groups

Each pupil, working alone, observes the frieze (drawings, plant collages, photographic slides, photographs) which he/she has obtained or the collective frieze and produces a short written text which corresponds to his/her account of the observation.

### Collectively

Joint exploitation of the previous work, i.e. oral description of the evolution of what has been observed during the development of the embryo. A video document (see CD ROM) showing the speeded-up germination of the pea or bean may help in the formulation of these results. The same result could also be achieved using a succession of views taken by a digital camera.

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[13]There are several possibilities:
- drawings of the observations made, with dates and measurements (in CE1) and with annotation of the remarks made individually or in small groups;
- photographs taken by the teacher or the children;
- for each observation, removal of a germinating seed and its placing in a herbarium in order to build up a frieze of dried samples which can be used to follow the various stages of germination.

A duplicated document may be used at this stage in the procedure: such a document covers the various stages of germination (pea or bean) in several stages and which will be annotated collectively or individually by the pupils.

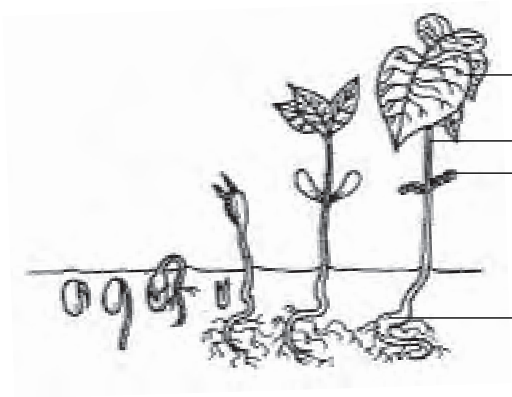



*Figure 10*. The various stages of germination. © SEAMEO RECSAM, Penang, 2007

**Individually**
Some pupils may return to the drawing from the anatomical observation of the seed made earlier and give a better description of the different parts of the seed. The notion of the seed has now been built up[14].

## Lesson 13. The role of the seed - the seed and its food reserves

Once the concept of the seed has been acquired, numerous extensions and appraisals are possible, at the initiative of the teacher. They may lead to collective or individualized activities such as the observation of other instances of germination undertaken in the classroom or at home, or discovered during an outing or even in documents (books, video film, Internet website...). This is the chance for the pupils to make comparisons which show similarities and differences and make them aware of the unity and diversity of living things.

These extensions arouse the pupils' curiosity about their environment, about the unity and diversity of living things, and about the relationships between these livings things within a common environment. Moreover, collections of samples or of substitute documents (for example, photographs) may be undertaken when it is required to preserve the living things. The next two lessons constitute extension courses centred around two themes: the seed's food reserves and the biological role of the so-called seed form.

The pupils seek to determine the importance of the specific role of the seed in the growth of flowering plants and, in particular, the socio-economic role of food seeds.

Experiments may be undertaken to confirm the role of the food reserves at the time of plant development: one might sow an embryo without its food reserves or with only half of the seed.
One experiment which is easy to perform and which aims to compare the first stages of germination in light and in darkness may be undertaken by the class. It would have the advantage of showing that exposure to light is not mandatory, since the seed is provided with the food reserves needed for the first stages of development of the seedling. This experiment would reinforce the idea that the seed is a form of food reserve.

[14]The seed contains an embryo or seedling and food reserves, protected by a coat. During germination the seed absorbs water. The seedling develops using its food reserves: it does not need soil, but it does need water. After the seedling has developed, the seed no longer exists (this remark may also be used to make the pupils aware of the notion of irreversible biological phenomena).

The development of the young plant may be followed beyond the use of its food reserves: the pupils may compare the development of young seedlings growing in soil or on another substrate (cotton wool or filter paper). They may also note the time at which the young leaves turn green. All these observations serve as starting points, in cycle 3, for the study of the nutritional needs of green plants.

Seeds contain food reserves which humans can use for themselves. One might, for example, look at the school meal menus and determine all the seeds and grains which are eaten as they are (beans, peas, chick peas, lentils...) or after transformations (grains of wheat).

One might make the link with history: seeds and pips have in the past always played an important role in the human diet since dehydrated foods are easily preserved when kept away from moisture. The evolution of the sciences has led to the development of techniques for preserving our food (preservation and freezing), which explains why nowadays our diet is always very varied in all seasons.

## Lesson 14. The role of the seed – unity and diversity of living things

The pupils seek to determine the importance of the specific role of the seed in the dissemination of the species.
One might construct classifications using objective criteria and relying on the literature, and thus accustom the pupils to the reading of short texts of a scientific nature.

**Collectively**
Questioning may be employed, for example, on a nature outing (which may be that of lesson 2). On their return to the classroom the pupils discover that they have brought back with them seeds and pips (seeds contained within a fruit) which have become attached to their clothes (soles of the boots, woollen clothes).
If an outing is not possible, seeds with an attachment system can be collected by the teacher and the effectiveness of the system demonstrated to the class during a period of collective questioning.
Similarly, a sample taken from forest litter (layer of leaves and humus) will reveal numerous small seeds, which may be carried away by a walker in a groove in the soles of his/her shoes.
One might touch upon the similarity between the ways in which seeds are dispersed by the pupils and by animals (paws, the fur of mammals, birds' feathers and the pupils' shoes and clothes). Pips and seeds may also fly off in the wind or be carried away by water.
In class, the pupils glue their dried collections on to white cardboard rectangles, thus building up a diverse collection, and then carry out classification activities: seeds and pips dispersed by the

*Figure 11*. Examples of seeds transported by the wind, by water or by animals.

wind (they are light and have systems for gliding in the air), by water (they have a waterproof coating and systems for floating on water) or by animals (seeds and pips may become attached to feathers and, above all, to fur, they then have an attachment mechanism which can be observed under the magnifying glass).
Often, seeds are ingested by animals and can sometimes be found in their faeces if the seed coat is resistant to digestion.
Recourse to documentary resources confirms the proposed classification for a number of familiar plants. Texts or cartoon strips illustrating the colonization of a habitat by plants may be used (for example, colonization of a desert island). One might talk about the original vegetation of slag heaps, due in part to pips transported by wood from elsewhere which has been used to shore up the mine galleries, or again about the first vegetation on a recent volcanic island, which is explained by seeds and pips brought by the sea, animals and the wind.
All flowering plants produce seeds, but seeds and pips may have a range of anatomical mechanisms to ensure the dispersal of the species in the near or distant surroundings. It may be useful to remark to the pupils that the seed is a form of dispersion which is specific to terrestrial plants (with some exceptions). This stage in the life cycle (the seed form) developed on Earth in flowering plants, thereby enabling them to withstand periods without water and to colonize new habitats.

## Conditions for the teaching of the module

### Materials for a group of 5 or 6 pupils

- a set of samples comprising a range of elements [seeds (lentils, beans, lettuce, garden cress, radishes, broad beans, corn, lawn seed, birdseed mixtures...), natural minerals (cat litter, gravel,...), non-living organic material (grains of semolina, small wooden balls...)];
- a polystyrene tub (packing case) and a number of smaller receptacles (mineral-water bottles with their tops cut off, yoghurt pots, ....);
- garden soil mixed with a little sand;
- a number of tools for us on the seed trays (for example, teaspoons);
- a watering can or a spray - wooden or wire markers used to carry labels;
- a hand-held magnifying glass (or magnifying binoculars);
- cotton wool, paper or blotting paper, some polystyrene blocks from packaging;
- small rectangles of cardboard and some glue.

### Precautions

The teacher will draw the young pupils' attention to the toxicity of certain seeds and certain fruits (ricin, yew, deadly nightshade, arum, morel, woody nightshade...) and will extract these from the samples if necessary. It is essential to respect the fundamental rules of hygiene: if soil is handled without gloves, one should wash one's hands and brush one's nails with soap.

### Duration

This module comprises 14 lessons of approximately one hour each, which can be brought together into five stages, each corresponding to an initial question session. This division is evidently modular.

### Recommended fact sheets

Useful information may be found in the following fact sheets: no. 4, `stages in the life of a living thing'; no. 5, `Common functions of living things'; no. 8, `Order in the living world'.

### Documents

- a speeded-up video film on germination (for example, germination of the pea, available from the Centre National de Documentation Pédagogique);
- documents which can be used to identify the seeds collected from certain trees and herbacious plants during an outing (for example, *Arbre, quel est ton nom?,* Raymond Tavernier, Bordas, 1978);
- documents which can be used to find out about the history of certain flowering plants (for example, *Histoire des fleurs,* Roselyne de Ayala and Mathilde Aycard, Paris, Perrin, 2001);
- Internet websites:
www.jardin.ch/dossiers/germination
www.snv.jussieu.fr/vie/dossiers/plantule

## Conclusion

This very rich module, which does not require any specific expensive equipment, can be taught by any cycle 2 teacher. The knowledge acquired relates solely to the concept of the seed: it is modest, but must be rigorous since it will be used in cycle 3 as the foundation stone for the development cycle of a flowering plant and in form 6, for the notion of the population of a habitat by plants.

The methodological skills developed, associated with the realization of an investigative approach are crucial in cycle 2; the young pupil embarks at his/her own initiative upon a dynamic learning process stimulated by his/her curiosity about the environment and by his/her own self-questioning. He/she becomes familiar with the use of observation and experiment to question his/her conceptions, to verify his/her hypotheses and to build up a corpus of knowledge and know-how, with the class.

### Sources

Pasteur elementary school, Vénissieux (69),
Marianne Cohn school, Annemasse (74),
the Jean-Marie Bouchard of the *La main à la pâte* team ,
Unesco Manual.

# What happens to the food we eat?

cycle 3

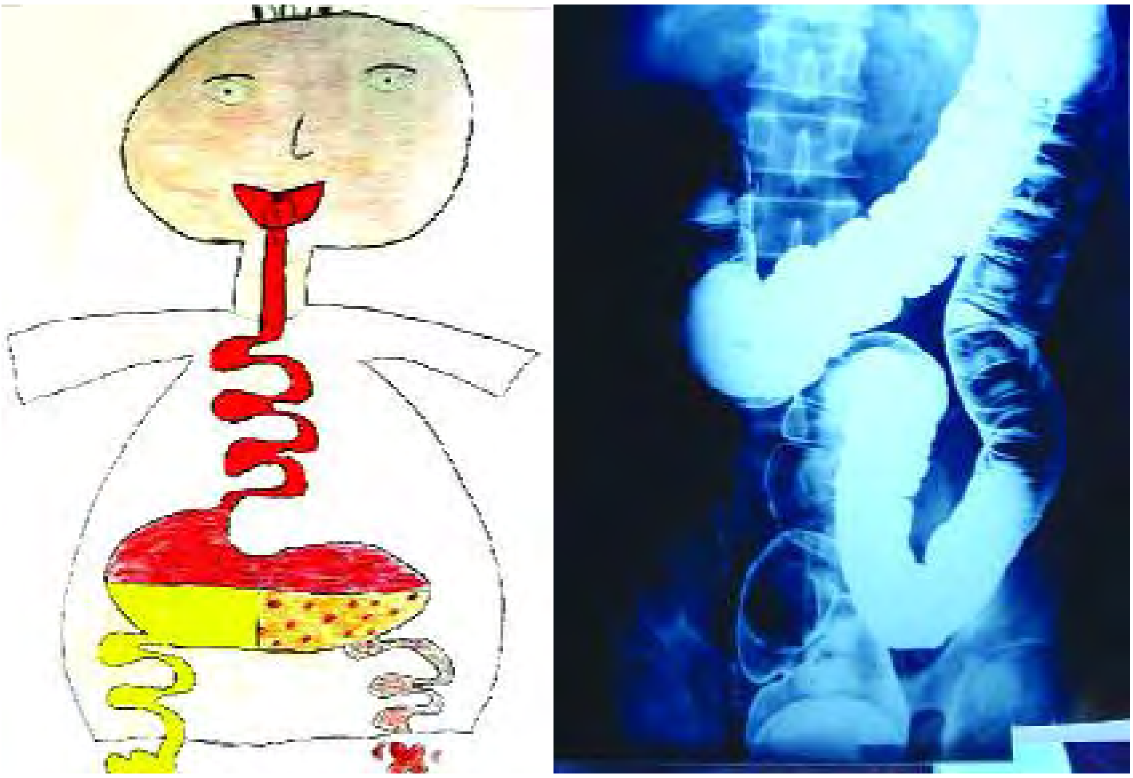


*Figure 1*

Every living organism has a fundamental need to eat. The human diet, an interdisciplinary topic par excellence, has both an individual and a collective dimension. Because every child, every family and every society maintains a particular relationship with food, understanding what happens to food in the body presents an opportunity to construct a common scientific basis, shared by all cultures and related to education and health. The ideas put forward here are not intended as a model. They suggest how an investigation may be run, with periods of personal research, as individuals or in groups, alternating with moments of summarizing in the whole class. They bring together orthogonal learning objectives: mastery of oral, written and pictorial language; documentary research; reasoning; comparison of the knowledge acquired by the children with established and published knowledge.
By way of complementary documentation, in addition to this text describing the typical course of the module, the CD ROM distributed with this book contains images and video clips which can be used with the pupils.

## Position in the programmes

- In cycle 1: sensory discovery activities, cookery experiments have been shown to give rise to observations and questions about diet. `What can I eat and what can't I eat?' `What do I like to eat and what don't I like?' `Where does vomit come from?' `What gives you strength?' The children have learnt to prepare simple dishes and to distinguish flavours: sweet, salty, acidic, bitter. They might have observed that a small object swallowed by mistake (cherry stone, plastic marble) turned up again in their stools. They know that young children can choke by swallowing peanuts the wrong way. They have observed that if they drink a lot they urinate more.

- In cycle 2: work on dietetics, on food hygiene and teeth will undoubtedly have led to the questions: `What is good eating?' `How can one eat well?' `What are our teeth for?' `How can we protect them?' . The pupils have discovered, in their families or at school, that some people follow special dietary regimes for medical reasons (inability to tolerate certain substances, need to lose weight), for aesthetic reasons or as part of intensive sporting activity.
- In cycle 3: a deeper investigation of dietary requirements leads to the discovery of the general organization of the digestive system and of the function of nutrition. Health education is founded upon a more scientific basis.

| Extracts from the programme | Extracts from the application document | |
|---|---|---|
| | **Specific skills** | **Remarks** |
| **The human body and health education** Initial introduction to the functions of nutrition (digestion, respiration and circulation). | Ability to describe the path and the transformations of food in the digestive tract and its passage into the blood. Ability to exploit documents (X-rays, books, multimedia). | A primarily functional approach is called for, starting from questions such as `what happens in your body to what you drink, to what you eat, to the air your breathe?', so as to establish the links between the different functions (respiration, digestion into small elements capable of passing through the wall of the digestive tract, they are carried away into all the organs of the body, whose operation they then permit). |

- At Collège: the chemical aspect of the transformation of food will be studied, together with the concepts of solubilization and diffusion.
- At the Lycée: the notions of exchange surfaces, chemical reactions and metabolism may be given greater depth, in connection with the concept of energy.

| Concepts involved, notions to be built up | 1st level of acquisition | 2nd level of acquisition |
|---|---|---|
| Food path | Cycle 2 | Cycle 3 |
| Mechanical transformations of food | Cycle 2 | Cycle 3 |
| Chemical transformation of food | Cycle 3 (evocation) | Collège - Lycée |
| Operation of digestive enzymes | | Lycée |
| Solubilization of food | Cycle 3 | Collège |
| Diffusion through a membrane | Cycle 3 | Collège |
| Passage of nutrients into the blood | Collège | Collège - Lycée |
| Notion of cells | Collège | Collège - Lycée |
| Cellular use of nutrients | Collège | Lycée |

# One possible way in which the module might be taught

A preliminary lesson on food serves to introduce the module.

| Lessons | Initial question | Activities undertaken with the pupils | Linguistic activities | Class organization | Knowledge and know-how brought into play |
|---|---|---|---|---|---|
| Lesson 1 | Where do the water and the bread go? | Collection and comparison of ideas | Pictorial, written, oral | Individually, in twos, as a whole class (comparisons) | Communicate via texts and diagrams, and then orally |
| Lesson 2 | What do you feel when you eat? | Self-observations, work on documents | Oral, written (account), diagrammatic | In twos, individually | Observe, draw an observational sketch |
| Lesson 3 | What happens when you swallow? | Construction of a model | Oral, pictorial (plans) | Group | Handling, reasoning |
| Lesson 4 | How does the digestive system work? | Observations on an animal. | Written (account of observations), oral (questions during the dissection) | Whole class (dissection), individually (account) | Observation, reasoning |
| Lesson 5 | What happens to food in the body? | Documentary research, summary | Reading, writing, oral activity | In twos, whole class | Search for information: library; documentation centre, Internet |
| Lesson 6 | | Evaluation | Pictorial, written | Individually | Review of the knowledge acquired during the module |

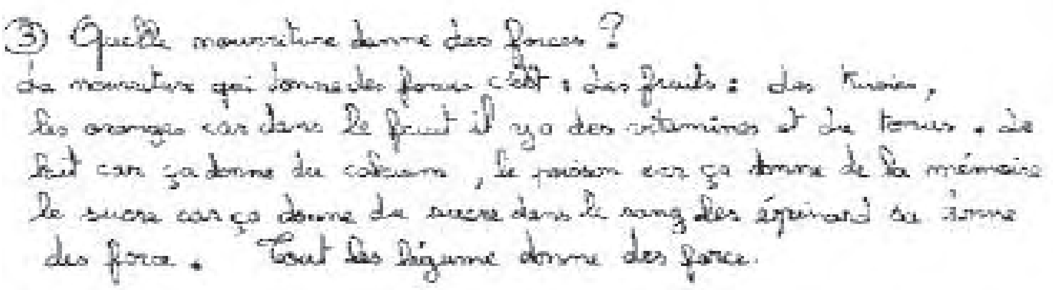
# Introduction and initial discussion of nutrition

### About food

There are many ways of introducing the topic of food**.** One might begin with a game about the families of foods or even ask each pupil to give his/her point of view on questions relating to food. Note that we do not eat all the time. The social dimension of meeting over a meal constitutes a reference point for dietetics: one might think about the consequences of snacking and the excessive consumption of fizzy drinks. While obesity threatens a growing number of individuals, malnutrition through lack of food is rampant in numerous countries.

Certain questions which the children ask their comrades during the debate in class are written up on the board: they serve to prolong individual reflection.
Each child responds in writing in the personal part of his/her experimental notebook and will use his/her notes to participate in the verbal exchange which will follow. Here are some examples of questions elicited by the teacher:
- “What is your favourite food?”
- “What don't you like?”
- “Which food gives you strength?”
- “What don't you like, but have to eat? Why?”
- “What happens when someone doesn't eat?”

**Debate and questions**
Extracts from the experimental notebooks of CM2 pupils are reproduced below:



*"Which food gives you strength? Foods which give strength: are fruit: kiwi fruit, oranges, because in fruit there are vitamins and energy. Milk because it gives calcium, fish because that helps the memory, sugar because that gives sugar in the blood, spinach gives you strength. All vegetables give you strength."*

*Figure 2.* Extract from M.'s experimental notebook.

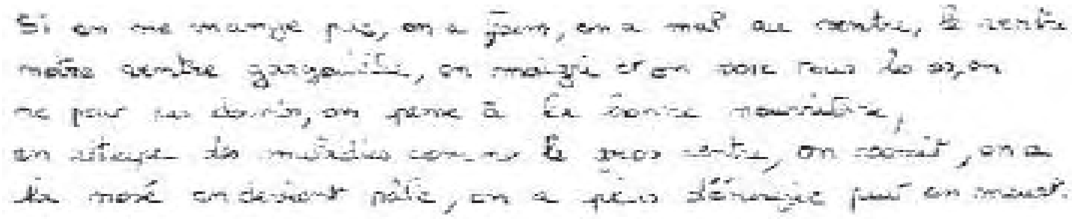
- Individual points of view:

Extract from L.'s notebook: Which food gives you strength? I think that the food which gives you strength is green vegetables, because they contain a lot of calcium and vitamins. That's why you have to eat plenty of vegetables.

Extract from R.'s notebook: The food which gives you strength is kiwi fruit, because it has vitamins. Also I think that spinach gives you strength. Soup also gives you strength because there are a lot of vitamins in it (...). I love fruit- and mint-flavoured sweets. What I don't like, which gives you strength, is spinach.

Extract from A.'s notebook: The foods which give you strength are: kiwi fruit, apples, pears and other fruits and cereals. Cereals are good for keeping you fit, but I don't like that.

- Account of a group discussion among four pupils.



*"If you don't eat, you get hungry, you have stomach ache, your stomach gurgles, you lose weight and all your bones stick out, you can't sleep, you think about good food, you pick up illnesses like stomach bugs, you are sick, you have nausea, you become pale, you have no energy, then you die."*

*Figure 3.*

The pupils all have an opinion on the question of diet. On the other hand, at this stage of the module, the word `strength' does not have a very precise meaning and is unconnected with the scientific concept of strength. It will be progressively replaced by the word `energy'. In this class, the children think that vitamins and calcium give `strength', which conforms to a notion often put across by advertisements. Moreover, they think that it is precisely the food they do not like to eat which gives `strength', undoubtedly because this is one of the arguments used by their parents to persuade them to eat these little appreciated foods.
At the start of the discussion, one question was retained: `Can the food we eat give strength to the body and also `make us grow'?
The teacher may suggest that the children should go and ask some sportsmen (if there is a club near the school) or a school doctor, or that they should look up in a book what one should eat and drink before and during a competition in order to have energy. A conversation with the person in charge of the school cafeteria might also be fruitful.
This discussion introduces several possible strands, and therefore several potential ways ahead. These strands, which have already been worked upon in cycle 2, can be studied at greater depth in cycle 3 and at Collège. The strand pursued below is mainly `mechanistic', as opposed to the `chemical' and `energy-related' strands which will be pursued at secondary school. It includes

suggestions for optional modules linked to more fundamental modules. How does our body apply food for its own purposes?   That is the main problem to be solved.

# Lesson 1. Where do the bread and the water go?

### Formulation of the problem and collection of initial conceptions

First of all the teacher should check that none of the children is following a special dietary regime. He/she then distributes bread and a glass of water to each pupil, in the guise of a snack. There then follows a discussion on what becomes of this food. `Which part of the body will the water and the bread go to?' He/she then distributes a sheet of paper showing the silhouette of a man, with the instructions: *Draw the paths of the bread and of the water. Name the places these foods pass through. What happens to these foods in the body?*

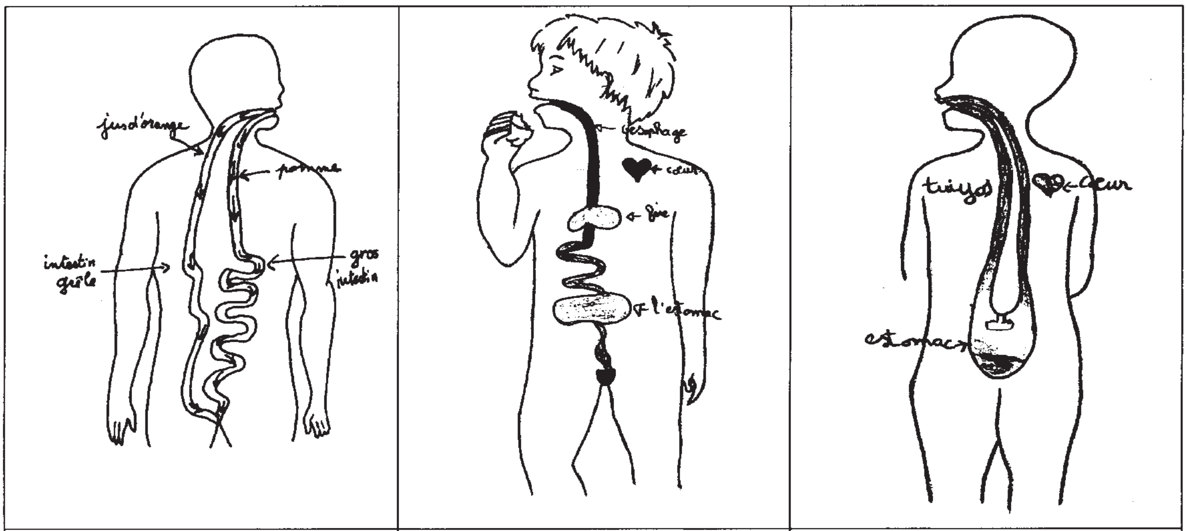
### Collective analysis of what the children produce

Comparison of the children's ideas can be initiated by an exchange of the sheets between neighbours. During the discussion the children will probably spontaneously use infantile vocabulary such as `wee wee' and `poo'. The teacher will choose the opportune moment to encourage them to acquire the corresponding scientific vocabulary, `urine' and `stools', taking every precaution to avoid situations which the pupils might find humiliating. The teacher collects the drawings, classifies them into several categories, puts together groups of children sharing the same ideas and asks them to make a poster, by way of a large type of picture.

### Collection of the pupils' questions and development of hypotheses

A reporter is designated in each group to step forward to explain to the whole class what he/she thinks becomes of the food. A collective discussion follows in which each group is able to defend its point of view freely in turn. This is not a search to find the right answer immediately, but a search for what might be.

The teacher writes down on the board or on a poster the questions the pupils asked during the phase of exchange and comparison of ideas. This is made easier by a presentation, using an overhead or video projector, of typical pictures produced by the class, scanned or copied onto a transparency. Here are some typical examples of pictures obtained (other examples are annexed on the CD ROM).




| 2 entrées, 2 tuyaux et 2 sorties | 1 entrée, 1 tuyau et 1 sortie | 1 ou 2 entrées, pas de sortie |
|---|---|---|

*"Two entries, two tubes and two exits*
jus d'orange = orange juice
pomme = apple
intestin grêle =small intestine
gros intestin = large intestine

*One entry, one tube and 1 exit*
oesophage = oesophagus
coeur = heart
foie = liver
l'estomac = stomach

*One or two entries, no exit*
tuyaux = tubes
coeur = heart
estomac = stomach "

*Figure 4*

The pupils disagree among themselves or seem to be stuck about the following:

| Path | Transformations | What happens |
|---|---|---|
| One or two entries?<br>One or two exits?<br>One or two tubes? | By the stomach?<br>How does digestion take place?<br>What is digestion?<br>What is indigestion?<br>What is vomit? | What happens to good and bad food?<br>Does water produce urine?<br>How is good food used?<br>Does the brain eat?<br>What is blood for? |

The lesson involving the comparison of early notions allows everyone to test his/her own ideas and to be motivated to seek proof and solid arguments in order to respond to the questions raised by the class.
The obstacles listed during this comparison might lead the class to undertake a range of activities, suggested by the children or set by the teacher. Choices must be made so as not to become involved in an excessively long or complex process. Some of the phenomena involved can be demonstrated experimentally or using models, the remainder will be dealt with during a documentary research phase (other approaches are suggested on the CD ROM).
At the end of this lesson, the class may retain the following hypothesis: `Liquids are assumed to go into a sack for liquids and produce urine, while solid foods take another route and produce stools'. This will be tested in the next lesson.

## Lesson 2. What do you feel when you eat?

### Self-investigation on one's own body

The teacher hands out bread and water to the pupils, with one mirror for each group of pupils. Here, sensory indications will be studied, in particular to determine where there is one tube or two, one for liquids and one for solids. What does each person feel when he/she eats?

During the collective preparation for the lesson, asks whether some of the class have already swallowed something the wrong way and how they explain that phenomenon.

Observation of the back of the throat and examination by touch at the level of the neck during swallowing do not provide an answer to the question, but seem to indicate that the entry for the liquid and solid elements is the same. Both liquid and solid foods can be swallowed the wrong way. Once chewed, even the solid elements become a sort of pulp, neither truly liquid nor truly solid. It is therefore improbable that the hypothesis of a separate tract for liquids and solids is valid (see other remarks by pupils annexed on the CD ROM).

### Investigation using scientific imagery (X-rays)[1]

This phase might be replaced or supplemented by the observation of X-rays of the digestive system provided by a doctor or the parent of a child.

The video *Le trajet des aliments* in the *Le corps humain* folder, Delagrave/CNDP (annexed on the CD ROM) is played to the class (1 min 30), preceded by a commentary and a question intended to set the direction for observations:

`This is a film taken in a hospital. The patient is made to drink a type of thick porridge which stops X-rays, or powerful rays of invisible light which can pass through the body. Radiography is the procedure which sends these rays into the patient and makes it possible to observe the inside of the body .'
`The thick porridge is assumed to follow the same path as food. What is this path?'

In order to answer this question, the pupils pause on the images as many times as they deem necessary and try to put together some text and a diagram in the personal part of their experimental notebooks.

[1]Optional phase.

There are various ways of arranging the discussion. If one has a projector, one can ask a pupil to sketch the thick porridge and its path in felt-tip on a large sheet of white paper, displayed on the screen or the wall. If one only has a television set or computer workstations, the same thing can be done by the various groups of pupils using tracing paper placed over the screen. Comparisons will be made between groups. Objective observation requires work to question personal points of view and frequent returns to the document to invalidate or confirm the assertions made by each pupil in his/her notebook.

Oral exchange makes it possible to highlight a number of corroborating indications which can be confirmed after a second observation of the film. Following a discussion, the children will have noted the following in the collective part of their experimental notebooks:

1. the thick porridge goes into the throat; it seems to hesitate between two paths, but it goes towards the tube situated at the back of the neck;
2. it goes down this tube
3. it goes into a sack;
4. it passes into a jagged tube, in a constant movement.

The hypothesis according to which liquids and solids would follow two different paths is invalid. There are in fact two tubes, but only one is used to carry food, whether liquid or solid. Documentary research (for example in an illustrated dictionary) shows that this tube down which all food passes is called the *oesophagus.* The sack is called the *stomach* and the jagged tube is called the *intestine.*

The second tube, situated at the front of the neck, is called the *trachea*. It takes the air to the lungs (should the children ask how food is guided towards the *oesophagus* tube rather than towards the *trachea* tube or what happens when something goes down the wrong way). An optional modelling activity, proposed in the first part of lesson 3, provides elements of the answer.

## Lesson 3. What happens when you swallow?

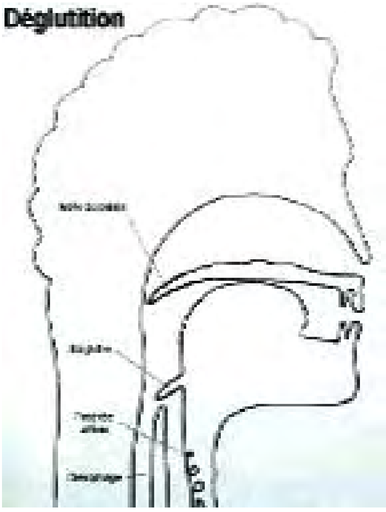
### Construction of a model[2]

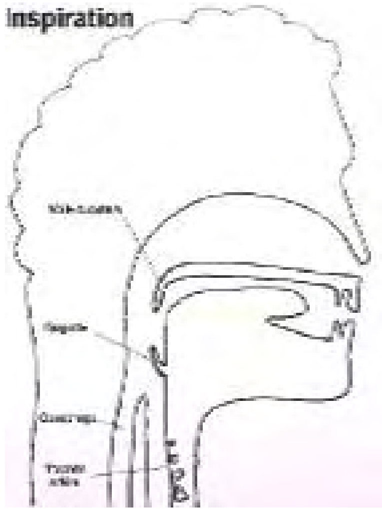
A model is constructed to model the operation of the natural safety valves, namely the *soft palate* and the *epiglottis* in the *pharynx,* in order to provide a better understanding of the junction of the respiratory and alimentary paths. For this, the teacher asks the pupils to note the parts of the throat which move during swallowing (the epiglottis moves to closed position over the orifice of the tracheal artery, situated in front of the oesophagus) and abruptly blocked nasal inhalation (the *soft palate* moves to isolate the nasal cavity in the mouth*).* The cross section of the throat, proposed in this document (or based on the bank of images) is built up by the pupils with moving elements and paper fasteners, according to their hypotheses. All solutions which disagree with direct observations or with the film images are progressively eliminated (see Figure 4).

### Following the path of food

The following stages will be enriched by additional X-rays distributed in the form of traceable photocopies (available on the CD ROM). These raw images are to be used to study the elements of the answer to the `pipework' question. The film gives a better idea of the digestive tract in dynamic operation and also of the contractions of the intestine, in particular. Images paused upon in the film and fixed X-ray images are easier to sketch and interpret. In this way, the pupils will be able to discover the jagged outline of the small intestine in a few particular places and to generalize the corresponding increase in the area of the exchange surface due to the numerous folds.

[2]Optional phase which can be used as a stage of intermediate assessment, at the beginning of lesson 4.




*Déglutition* = swallowing

“voile du palais = *soft palate*
épiglotte = *epiglottis*
trachée artère = *tracheal artery*
oesophage = *oesophagus*
langue = *tongue*

attaches parisiennes = *paper fasteners”*

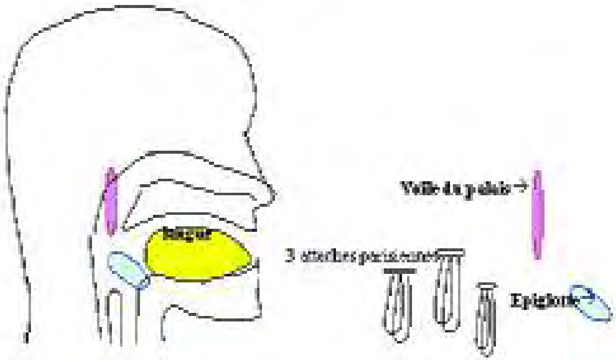


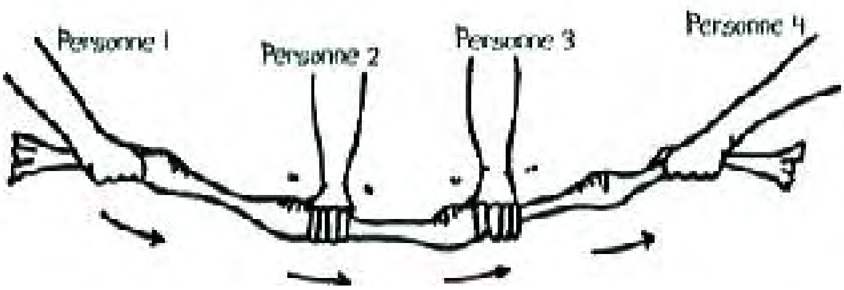

*Figure 5.* Moving elements of the model which might be constructed: *tongue, epiglottis and soft palate.*

## How does food move from the mouth to the end of the intestine?

If this question is selected, the explanations suggested by the pupils will vary: most often they think that food falls under gravity. The apprehension of the facts that the digestive tract is coiled up and folded back upon itself several times and that digestion proceeds well at night when one is lying down leads to surprise and disproves the last hypothesis. Showing of the radiographic film, *Le Trajet des aliments,* reveals that there are movements which pupils can hear (rumbling noises) by placing their head on their neighbour's stomach.

The new hypotheses which are put forward can be tested using a device described on
www.inrp.fr/lamap/activites/insights/corps_humain/
www.inrp.fr/lamap/activites/insights/corps_humain/sequences/accueil.html

The problem which arises is the following: given a muff made out of a nylon stocking and ping-pong balls, how do you pass the balls from one end of the muff to the other?




*“1st person, 2nd person, 3rd person, 4th person .” Figure 6*

In their experiments, the pupils will simulate the principle of peristsalsis; that is, contractions progressing in waves along the intestine.

### Modelling the digestive tract

Other information can be deduced from radiographic images:
- estimation of the size of the stomach, by comparison with known receptacles;
- estimation of the length of the intestine, by scale calculations on a fixed image (mathematical activity).

A model of the digestive tract is then constructed using an old hosepipe or a rope of length approximately 10 m, plastic bags, diagrams and labels indicating the digestive tract organs. This model can be used to give a better idea of the size of the digestive tract when unrolled. It helps one to understand how a large exchange surface promotes the passage of nutrients into the blood (subsequent lessons). It has its limits: constant diameter of the rope; no folds; no link with the blood system...and it would be desirable, when possible, and with the necessary precautions (see Lesson 4, `Observations on a dissected animal'), to carry out a dissection of a whole rabbit or chicken in order to give an idea of the size and the actual shape of the digestive tract and its relationships to other organs.

### Schematization of the digestive tract

The distribution of incomplete diagrams to be reconstructed and labelled allows the class to bring this part to a conclusion and retain the essential elements.
The digestive system reconstructed in this way can be repositioned in a more general scheme in which the respiratory system and the circulatory system will be progressively involved.

## Lesson 4. How does the digestive system work?

### Observations on one's own body

The amount of food taken in can be compared with the amount of waste excreted. Estimates to an order of magnitude can be made using approximate measurements

| | | |
|---|---|---|
| An orange: 100 g | A glass of water: 100 g | A plate of pasta: 200 g |
| A dessertspoonful of sugar or a sugar lump: 5 g | Daily stools: 200 g | Daily urine: approximately 1 kg for a child, but more than twice as much for an adult |

This type of comparison shows that a large proportion of the food is not rejected in stools and urine
The hypotheses on the role of food, collected during the first lesson, are then recalled. They provide a partial answer to the question; some of the food is used to repair and replace hair and dead skin (dandruff...) which our body produces continuously and to provide for the growth of children, while some of the food is consumed in the production of energy by respiration. It remains to determine where and how food passes into the body to play its nutritional role.

*N.B.* - The dietary role of food and the notion of a balanced diet are not discussed in this module. This part of the programme, which is very important for the pupils' health education, will have been covered before this module or will be covered afterwards.

- Investigation at home:

What remedies are used for the various common digestive problems?
- all bicarbonate of soda derivatives for indigestion;
- medicines for diarrhoea and vomiting;
- medicines or high-fibre foods for constipation.

This information collected at home will provide an awareness of the social importance of digestion. One might also collect expressions relating to nutrition (“Bon appétit!”).

## Observations on a dissected animal or on photographs of dissections[3]

Better than a film or a set of iconographic documents, a dissection of a whole rabbit or chicken allows one to test the pupils' hypotheses.
*N.B.* – Warning! Dissections of vertebrates are only authorised under strict conditions, which forbid, in particular, dissections of wild mammals and handling by pupils (in France, NS. 85-179 of 30 April 1985, BO no. 20 of 16 May 1985).

The recommended method for dissecting an animal is described in *Le Corps humain* by Raymond Tavernier (Bordas, 1972[4]). The equipment needed includes a cork or wooden tray, latex gloves, good scissors, a scalpel or a cutter, pins, thin sticks (such as chopsticks, for example) which can be used as cannulas to check the course of the `tubes'. Delicately performed by the teacher, the dissection can be carried out in front of half a class, arranged in an arc of a circle, while the other half carries out research work on documents. The pupils ask the teacher to check their hypotheses: for example, to use the cannula to exhibit the continuity between the stomach and the intestine.

The teacher makes an incision in the abdomen, as shown in Figure 7, from the pubis to the thorax. This makes it possible to open the abdomen in two flaps, each of which is pinned onto a board (Figure 8). Progressing along the intestine, one sees the change in the *bolus*.

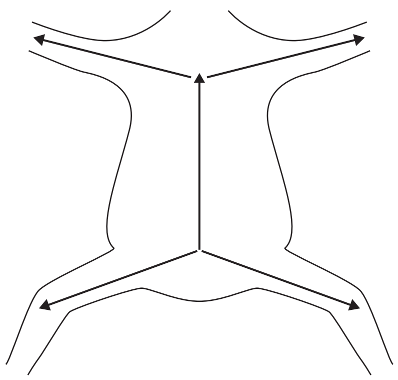


*Figure 7*

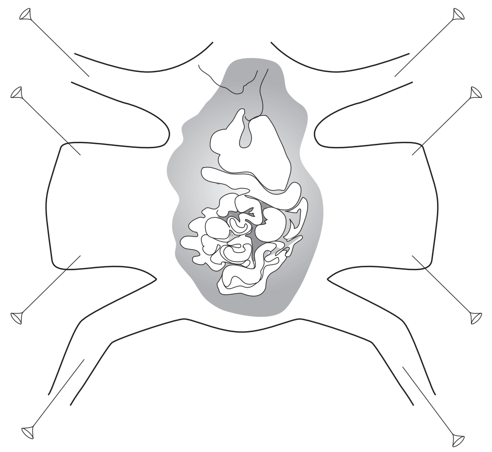


*Figure 8*

Recently ingested food is seen in the oesophagus and the stomach (the *crop* and then the *gizzard* in a chicken). On can then follow it right through the small intestine, the caecum and the large intestine, which can be unfurled. Unlike the digestive tract of mammals, that of the chicken contains a very large and muscular gizzard which often contains small stones, permitting the grinding of grain.

That of the rabbit contains a voluminous intestine, which facilitates the digestion of grass, particularly at the level of the *caecum* (entrance to the large intestine). The transformation of the bolus between entering and leaving the digestive tract can be exhibited. The rich vascularization of the walls of the digestive tract can also be observed.

## Stage assessment

The class is questioned as a group, keywords are noted on the board and an attempt at an initial summary is made. There is no such thing as good or bad food. Some foods withstand digestion and are not ground down (for example, vegetable fibres). Others do not withstand it and are reduced to small pieces. A simulation experiment using a coffee filter shows that water can carry fine particles with it, while the largest particles remain stuck in the filter. A sugar lump, even when reduced to powder, will not pass through the filter. On the other hand, water may dissolve this sugar and allow all of it to pass through. Food undergoes mechanical transformations, and also chemical transformations which will be studied at Collège. A discussion about the origin of the sweet taste of a mouthful of bread which is chewed for a long time or the smell of vomit may lead to the introduction of this notion, without going into greater depth.

[3]Optional.
[4]For consultation in a library.

## Lesson 5. What happens to food in the body?

A number of problems remain to be resolved: where does food pass into the body? How will ingested food be used in and by the body as a whole?

### Documentary research

The procedures previously used (observations on living things and on scientific images, experimentation, construction of models) are not sufficient to answer these questions. Research into established knowledge of the subject is now necessary. This will be used to develop a more successful synthesis of ideas and to compare the results collected by the class with those established by scientists (which are based on medical cases and investigation techniques to which the pupils do not have access).

The class is split into two groups each of which will carry out research, the first half in the library and the second half on the Internet.

Advice given:

*Find simple texts (maximum 10 lines), scientific images and diagrams which will provide a full or partial answer to the two questions: how does food pass into the body? How will the digested food be used throughout the body?*

**Sheet: Research on the Internet**

1. I chose the search engine: www …………………………………………………………………
2. The keywords I chose: ……………………………………………………………………………
   (or chosen with the teacher: digestion, nutriments, intestinal absorption, nutrition...)
3. From all the sites suggested, I chose the first site whose summary seemed the simplest and the most appropriate: …………………………………………………………………………………
4. On the site I found most interesting, I found the information in: ……………………………..…..
   …………………………………………………………………………………………………….
5. Text taken from there: (most interesting phrase for our enquiry)
   …………………………………………………………………………………………………….
   …………………………………………………………………………………………………….
   …………………………………………………………………………………………………….
6. Scientific image found: (description and address)

7. Text span chosen: (description and address)

**Sheet: Research in the school library**

1. I used the bookshelves labelled: ………………………………………………………………….
2. The book I chose has the following title which seems to correspond to my research: …………..
   …………………………………………………………………………………………………….
3. I chose the following chapter from the table of contents: ……………………………………..
   …………………………………………………………………………………………………….
4. The text I selected consists of:

5. Text selected:
   …………………………………………………………………………………………………….
   …………………………………………………………………………………………………….
   ……………………………………………………………………………………………………

Scientific image found: (description and page)

Text span selected: (description and page):

*N.B.* - The sheets `Research on the Internet' and `Research in the school library' are in the CD ROM.

### Collective summarizing based on documentary research

The two halves of the class return to form the full class again, the teacher having first collected the papers from the documentary `collections' and prepared a number of texts and images and text spans to supplement this collection. He/she distributes the following four topics among the four groups of six to eight pupils:

- group 1: what becomes of food in the digestive system;
- group 2: role of the blood;
- group 3: what becomes of food in the body;
- group 4: general theme of nutrition (digestion, circulation, excretion).

This reorganization provides each pupil with the opportunity to write down in his/her experimental notebook what he/she has learnt from the collective summary. The teacher has prepared a photocopy of a complete diagram of the circulatory system and the digestive system. He/she uses tracing paper to superimpose these systems in order to highlight the connections. Here are some examples of phrases which can be noted in the collective part of the experimental notebook:

"The food we eat is transformed and cut up into fine pieces. There is no separation of solid and liquid foods. Food which is small in size then passes through the small intestine into the blood which transports it to all our organs, where it provides energy (sugars, fats), and forms structural elements (calcium, proteins) or functional elements (water, vitamins). "

"Food which is not sufficiently well cut up (not digested) passes into the large intestine and is then expelled through the anus in the form of stools. "

"Waste which is expelled into the blood by all our organs is filtered by the kidneys and goes into urine."

*Digestion* denotes the transformation of food into material of a small size. *Absorption* denotes the passage through the wall of the intestines. These two phases are then followed by the *transportation by the blood* and the *delivery to the organs* (allowing the release of energy and the growth and renewal of tissues).

The role of respiration in nutrition will be studied after work on pulmonary ventilation and respiration. It is vital to make the link between respiration and food, since the purpose of respiration is to provide all the cells of all parts of the body with oxygen. Oxygen permits the oxidation of nutrients transported by the blood to the cells where chemical reaction releases energy. Carbon dioxide produced from the oxidation of nutrients is removed from the body cells and delivered to organs that eliminate them from the body. These two phrases, correspond to a level of formulation which will only become accessible at Collège. In cycle 3, it is sufficient to understand that there are connections between these two functions: a sporting exercise requires both appropriate food and good pulmonary ventilation (to avoid cramps due to inadequate oxidation of the food and production of lactic acid in the muscles).

## Lesson 6. Evaluation

Given a silhouette of a child, the pupils are again asked to draw the path of food in the body.

The practical experiments described in Lesson 3 may be required.

More explicit questions make it possible to determine whether a pupil is able to apply the knowledge acquired during that lesson.

*Explain why when you eat rabbit or carrots you do not become part rabbit or part carrot.* The food undergoes transformations, it enters our bodies and is used as material with which to build our bodies (growth, putting on weight) and to provide energy (our needs increase when we move).

*Look at and describe your growth curve as a baby on your health card . What enabled you to grow and put on weight?* A baby grows and puts on weight thanks to food. Milk contains all the necessary substances. There are also losses. Only part of what a baby eats enters its body through the blood. Food enables children to grow and provides energy.

The assessments proposed by way of example enable one to follow the evolution of the children's ideas between the beginning and the end of the module. Examples of acceptable formulations for cycle 3 are given on the website
www.ac-toulouse.fr/ariege-education/sciences09/programmation_biologie.PDF
(a science room in Ariège) with formulations appropriate to cycle 1 and cycle 2 given for comparison purposes.

## Conditions for the teaching of the module

### Materials and documents
- X-rays of the digestive tract, for example in *Le corps humain*, Tavernier, Bordas
- A film, for example *Le trajet des aliments* in *Le corps humain*, Delagrave/CNDP
- Materials for building models of the digestive tract: flexible tubes, plastic bags, string (10 m), cardboard, scissors, paper fasteners...
- Images from endoscopy of the digestive tract (for instance, the CD ROM *Les mystères du corps humain* Hachette)

### Precautions
This subject concerns the child's body, its privacy and also its integrity. It is thus essential to respect everyone's sensitivity.
If dissection of a rabbit or a chicken is planned, some pupils may feel ill at the sight of blood (consult service note no. 85-179 of 30 April 1985, and BO no. 20 of 16 May 1985 concerning the protection of animals and the possibilities for dissection in the classroom). Words of explanation often allay these problems. Once this delicate moment has been passed, the pupils' contributions are often greater.

### Duration
Six to eight lessons of approximately 45 minutes each with CM1 and CM2 classes. Depending upon the study objectives, more time may be spent upon the production of written, graphical or technological work (model, presentations). Different lengths of time may be assigned to different points of the programme. In this example, a volontary decision was taken to undertake an extended range of practical activities to show the different investigation methods the pupils may be required to use during the year. The teacher should emphasize whatever is best suited to the objectives he/she has established with his/her class.

### Recommended fact sheets
See sheets no. 12 `Animal and human nutrition: digestion and excretion' and no. 15 `Health education'.

## Conclusion

Certain digressions should be avoided. Work which overemphasizes *mastication* (mechanical destruction of food) and the role of *saliva* (chemical destruction of food) risks giving the pupils the erroneous idea that all digestion takes place in the mouth. It should be made clear that this only concerns sugars. Mastication is just a preliminary stage of the mechanical destruction. The major part of mechanical destruction takes place in the stomach, otherwise one would have to spend hours chewing (vomit, which corresponds to the physical state of food in the food sack which is the stomach sometimes contains large pieces). Digestion is greatly facilitated by acidic *hydroloysis* of food (the stomach secretes hydrochloric acid). This notion can be introduced by showing that the stomach is a grinding muscle, although the same is not true of the intestine, and that when acid is poured on food the latter disintegrates quite quickly. The most important part of chemical destruction of food takes place in the small intestine thanks to the digestive enzymes. The stomach is essentially a bag closed by a vent (*pyloric sphincter*) which kneads and reduces the food to a porridge-like state. It is only when the food is reduced to this physical state (suspension) that the vent opens periodically to allow the porridge to pass into the intestine. The gastric stage lasts a long time (several hours).

Water is not a food like other foods. It is a solvent which is vital for the life of cells, that is for our organs (muscles, brain, digestive tract, blood vessels...). There is a small `internal lake' in our body (comprising the extra-cellular space) in which all our cells bathe. Water represents approximately, 60% of the weight of our body. The water we drink passes into the blood and then into the `internal lake', and the excess when we drink a lot is discharged in urine (like an overflowing bath!). One can be thirsty without being hungry, for example after transpiring a lot (the level in the bath is too low). This is fundamental because water is a solvent for salts and when we do not have enough water the increase in the concentration of salts leads to thirst. *Urine* contains some of the waste products from the activity of the organism's cells (for example, *urea*) for which water is a solvent. *Urine* is the result of filtering of the blood, which permits the evacuation of these waste products (the rest is carbon dioxide, evacuated through the lungs).

The processes of evacuation of the stools, on the one hand, and urine, on the other hand, differ in their nature. The *stools* contain waste products from food which has remained in the organism's `external environment' (in fact, the cavity of the digestive tract; from the mouth to the anus, is directly connected to the exterior). On the other hand, urine contains the waste products coming from the activity of the organs, whence from the interior of the body, from the `internal environment'. They are rejected in the blood and then filtered out and excreted by the kidneys.

## Selection of relevant websites

### Websites which can be consulted and used by the teacher when preparing the course

- *La main à la pâte* (hands on): www.inrp.fr/lamap/activites/corps-humain/accueil.html
- The school of sciences in Bergerac
www.perigord.tm.fr/ecole-sciences/PAGES/Accueil.htm
and, in particular:
www.perigord.tm.fr/ecole-sciences/PAGES/CORPSHUM/CorpsHum.htm
- A science room in Ariège, including under the heading of resources, an example of activity programming in biology in the three cycles:
www.ac-toulouse.fr/ariege-education/sciences09/programmation_biologie.PDF

### Websites useful for pupils in their documentary research phase

- Experiments on digestion (`smart kids', Palais de la découverte):
www.palais-decouverte.fr/feteint/juniors/html/exp.htm
- Junior encyclopedia with an article and a file on digestion from the school of Saint-Vallier:
www.momes.net/dictionnaire/index.html
- Supplementary information on the digestive system in `science files, human body':
www.chez.com/haplosciences/index2.html
- A national image bank: www.bsip.com/homeF/
- Real cross-sections of a human body (interesting, but difficult to interpret):
www.medean.luc.edu/lumen/MedEd/GrossAnatomy/cross_section/index.html

### Sources

These ideas have been tested in several CM classes in the Île-de-France in 2000 and 2001.

# What time is it in Paris, Beijing or Sydney ? – Study of time zones

cycle 3

This module provides an introduction to the study of the Earth's rotation on its own axis and, in a simplified way, to some of its consequences: the alternation of day and night and time zones. The foreign cities, Beijing and Sydney, have been chosen in the examples given, not only because the organization of the Olympic Games (past and future) has made them famous, but also because their position on the Earth has advantages for teaching purposes, as we shall see later:

- Sydney is in the Southern Hemisphere and its meridian is approximately opposite that of Paris, so that it is possible to say that `when it is day time in Paris it is night time in Sydney';
- The meridian of Paris and that of Beijing, roughly speaking, form an angle close to a right-angle, so that it is possible to say that `when it is midday in Paris, night is falling in Beijing'.

The knowledge that the pupils will have to build up in this module will not be described in more detail.

## Position in the programmes

| Extracts from the programme | Extracts from the application document | |
|---|---|---|
| | Specific skills | Remarks |
| The Heavens and the Earth<br><br>- The Earth's rotation and its consequences. | Based on elementary physical modelling<br><br>light source), pupils should gain the ability to examine various hypotheses capable of explaining the alternation of day and night and to conclude that no observation technique with which they are familiar allows them to decide between these hypotheses.<br>They should know that the Earth rotates once around its own axis in 24 hours.<br>They should learn how to determine the direction of the Earth's rotation on its own axis based on observation of the apparent movement of the Sun.<br>Based on a model or a diagram, they should be able to give an approximate estimate of the time at a particular place and thus understand the principle of time zones. | Work to be led in conjunction with history and, in particular, with the history of ideas about the Solar System (geocentricity, heliocentricity).<br><br>It is the reasoning that is followed which is important, not rote learning of the direction<br><br>A simplified representation of the Earth, taking into account four periods (morning, afternoon, start of the night, end of the night). Details of time zones and the dateline are not in the programme.<br>Here we distinguish between the instant in time (identical everywhere on Earth) and the local time (depending on location). |

This module may also be echoed in part of the geography programme (`Comparison of global representations of the Earth' in the section `View of the World: spaces established by human societies') and enable pupils to acquire some of the skills targetted in that course:
- to be able to carry out research using a printed atlas and using a digital atlas;
- to acquire and retain basic geographical vocabulary (and be able to use it in an appropriate context).

The international dimension of learning a foreign language, an integral part of the programme of that course, may also be covered in this module, which lends itself to Internet exchanges with foreign schools and to the formulation of a few simple phrases. In French: *Il est midi à Paris, quelle heure est-il à Sydney?*...In Chinese:

法国时间是十二点，现在是中国时间几点？

Moreover, this first knowledge of astronomy, marks the beginning of a learning curve which will be pursued in subsequent schooling. At primary school, other observations are complementary: the apparent movement of the Sun with respect to the horizon and its evolution during the year; the times of sunrise and sunset and their evolution during the year. These observations will give rise to an initial modelling, and to a first level of explanation which will be extended at Collège and at the Lycée.
- In the primary school: time is related (explicit details are not given) to the apparent movement of the Sun; it is not identical everywhere on the Earth. Self shadow: the Earth itself has an illuminated part facing towards the Sun and a part in shadow. The rotation of the Earth about its own axis and its consequences: time-zone principle. The revolution of the Earth and the Planets around the Sun, considered to be circular.
- At Collège: the revolution of the Earth around the Sun. Explanation of the seasons. Concepts of force, weight and mass.
- At the Lycée: universal gravity. Newton's Second Law. Kepler's Laws. Modelling of the uniform motion of a satellite or a planet.

**Knowledge and know-how to be acquired at the end of the module**
- To understand that the rotation of the Earth about its own axis facing the Sun has the consequence that time is not identical everywhere on the Earth.

- To be able to determine the direction of the Earth's rotation about its own axis, knowing the daily movement of the Sun relative to the horizon (to be acquired)
- To be able to position cities on a ball representing the globe, based on their position on a planisphere.
- To know the following vocabulary: hemisphere, equator, meridian, poles
- To be able to use a map of time zones graduated at hourly intervals
- To be able to use a model to indicate on it the time of day in different countries.

## One possible way in which the module might be taught

The approach is based upon the following introductory question: How is it that at the same moment, the time is not identical in two distant cities on the Earth? The question is complex. Its resolution requires the coordinated use of several items of knowledge:
- the rotating movement of the Earth about its own axis and its consequences on the alternation of day and night;
- the time at a particular place, determined by the position of the meridian of that place with respect to the Sun;
- elements on the globe used for reference purposes (meridian, Equator, poles, hemispheres).

The subjective approach involves not viewing these different items of knowledge as prerequisites which must be dealt with before considering time zones, but instead giving the initial question the role of a `guiding thread' which forces one to acquire these more specific items of knowledge in passing.

However certain prerequisites still remain:
- the time zone question requires the knowledge that the Earth is spherical in order that it can be dealt with in even a simplified way[1] ;
- the fact that time is not identical everywhere on the Earth must be known to the pupils before they become involved in the search for explanations. This is the case in general although a very elementary initial level of knowledge suffices (`when it is day here, it is night on the other side of the Earth).

| Lessons | Starting question | Activities undertaken with the pupils | Scientific approach | Conclusion from the lesson, outcome |
|---|---|---|---|---|
| Preliminary lesson | Observation of the course of the Sun during a day | Observation | Observation | The Sun reaches the highest point on its path at around midday on our watches |
| Lesson 1 | How do we determine the time in a distant country? | Use of a time-zone map | Formulation of objective questions | The pupils know how to use the map |
| Lesson 2 | When it is midday in Paris, why is it night in Sydney? | Collection and comparison of ideas | First hypotheses | The pupils have a poor mastery of the vocabulary which needs to be improved |
| Lesson 3 | Development of vocabulary (poles, equator, hemispheres, meridian, etc.) | Documentary research | Documentary research | Vocabulary is built up. The Equator and a meridian are traced on a polystyrene ball. Paris and Sydney are located on the ball. |
| Lesson 4 | What time is it in Sydney when it is midday in Paris? | Use of a model: spotlight + white ball | First simulations | When one of the two cities is in the Sun, the other is in shadow |
| Lessons 5 and 6 | How can one explain the alternation of day and night? | More systematic learning about how to use the model. Confrontation of the hypotheses against the model. | Hypotheses and first experiments | The model cannot be used to decide between different hypotheses. However, it is established that the Earth rotates about its own axis facing the Sun. |

[1]Although this fact is difficult to grasp, it is in general sufficiently stable in cycle 3 for the module to be taught.

| Lessons | Starting question | Activities undertaken with the pupils | Scientific approach | Conclusion from the lesson, outcome |
|---|---|---|---|---|
| Lesson 7 | What time is it in Beijing when it is midday in Paris? | Research using the model | Emergence of a question | To know this, one has to know the direction in which the Earth rotates about its own axis. |
| Lesson 8 | In which direction does the Earth rotate about its own axis? | Experimentation: spotlight and white ball | Reasoning | The Sun moves from the left to right before our eyes, therefore the Earth, viewed from the North Pole rotates about its own axis in the opposite direction |
| Lesson 9 | Return to the question of Lesson 7: what time is it in Beijing when it is midday in Paris? | Experimentation with the model | Solution | Knowing the direction in which the Earth rotates about its own axis, the pupils answer the question and invent others |
| Lesson 10 | How can we record what we have learnt? | Two-dimensional representation using various drawings | Schematic drawing | Construction of a two-dimensional model, adding of labels to photographs and diagrams |

The above division into lessons is only an example which will, of course, be adjusted by each teacher according to his/her class, its progress and the programme plans established for the cycle. Lesson 3 is only of interest if the pupils find that they are unable to express their thoughts correctly without a precise vocabulary. It is by no means certain that it should take place at this point in procedures. The teacher must determine the opportune moment, remembering that the definitions only become necessary once the background (the meaning) is firmly in place. Neither is it obligatory to devote a whole lesson to documentary research. Another possibility would be to encourage the pupils to check the meaning of the words they are using if they feel uncertain or if discussions with others reveal disagreements. Lesson 4 is easy and short. Some teachers prefer to incorporate its contents into Lesson 2, when they will show the pupils where to place Paris and Sydney on the ball.

The module can be split into two parts, one studied in CM1, the other in CM2. In this case, we suggest the following split:
- In CM1. Posing of the problem of the time in different cities. This is answered using a planisphere and a model (spotlight, ball), showing the pupils the direction of the Earth's rotation about its own axis, which is the main difficulty of the module.
- In CM2: After a lesson to refresh the memory, several lessons would be devoted to reflection on possible explanations for the alternation of day and night and on the question of the direction of the Earth's rotation about its own axis in connection with the difficult problem of relative movement.

## Preliminary lesson. Observation of the course of the Sun during a day

The actual teaching activity here is not described in detail. However, we recall the skills which should be acquired at the end of this preliminary lesson:

- no confusion between time and duration;
- simplified description of the apparent movement of the Sun during a day.

## Lesson 1. How do we determine the time in a distant country ?

This lesson is used to share the information which everyone has about time differences (the time is not the same everywhere on the Earth) and to learn how to use a simplified time-zone map.

### Collectively: setting the scene

It is desirable to be able to fall back upon precise and objective facts. Thus, the teacher presents the problem with reference, where possible, to an event in the news (video clip...) adopting an enigmatic attitude: How is that possible? It is evening in Paris and midday in such and such a country!... Can that be true? Does that surprise you? The pupils put forward their thoughts and share their knowledge and their experiences. The teacher does not confirm anything that is said. He/she merely leads the exchanges and commits them to memory

### Individually

Each pupil has a time-zone map on which a number of large cities are marked (Annex 1). He/she has to answer questions such as the following:
- "It is midday in Paris, what time is it in Beijing?"
- "It is 8 am in Paris, what time is it in New York?"
- "It is 2 pm in Moscow, what time is it in Dakar?"
- "It is 3 pm in Mexico, what time is it in Delhi?" Etc.

### In small groups

The pupils compare their answers**.** If they agree, they invent and ask themselves new questions. If they disagree, they refer to the teacher who, if necessary, suggests they use the second moveable strip (see Annex 1).

### Collectively

The teacher recapitulates  about how to use the map and, in conclusion, asks the pupils to collect evidence about time differences from the adults close to them. In addition, and taking care not to overload the lesson, it is interesting to formulate other remarks:
- there are 24 time zones because there are 24 hours in a day;
- the time in metropolitan France has been taken as a reference. This is convenient because we live there and because that corresponds to a historical role played by European countries, but it is arbitrary. The same map could be graduated around another origin.

## Lesson 2. When it is midday in Paris, why  is it night in Sydney ?

The pupils seek to explain why the time is not identical everywhere on the Earth. In their formulations they use a vocabulary with which they are not very familiar. The aim of the lesson is to make them aware of the need for a precise definition of the terms which they are using.

### Collectively

The teacher puts across the point using the complementary information which the pupils have obtained. He/she then proposes the following work: `Try to explain why, when it is midday in Paris, it is night in Sydney'. In the first instance, the question is limited to two cities lying on two quite opposite meridians and to a particular instant in time (for the present, we are only interested in the phenomenon of day and night).

**In small groups**
The pupils create a poster in which they use text and diagrams to formulate the explanation they think of.
Many groups formulate explanations which `go in the right direction'. Some can be accepted for the time being. `The Sun does not illuminate everywhere at the same time'. `The Sun cannot illuminate Paris and Sydney at the same time'. `Paris is on one side of the Earth, Sydney is on the other side...'. At the same time, it is clear that the pupils are confused and often use a vocabulary which they do not understand properly. `Paris and Sydney are not in the same hemisphere'. `Paris is on top, Sydney is underneath'. `Sydney is on the Equator, but Paris is not...', etc.

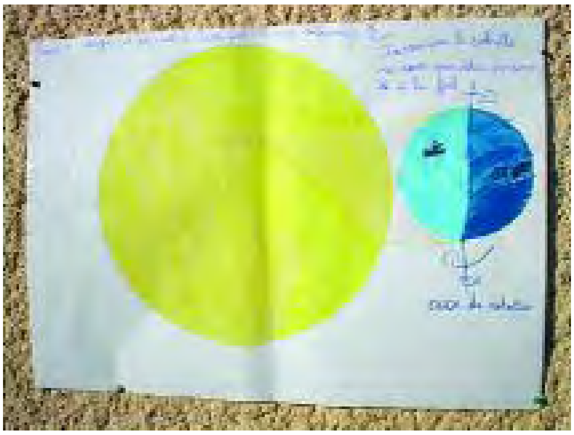


*Figure 1*

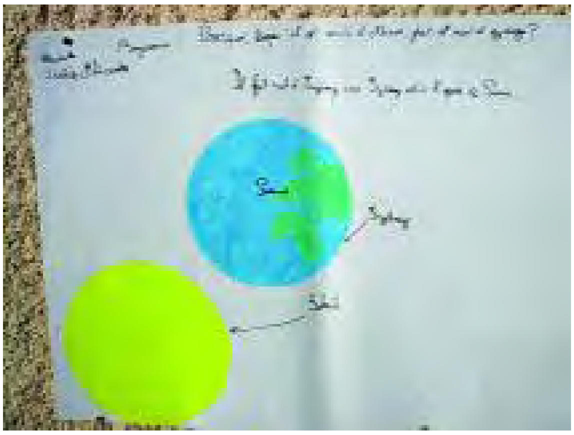


*Figure 2*

**Collectively**
The pupils put forward the explanations they have formulated.
The teacher lists the words and the expressions which the pupils use (see above) and retains the list with the following lesson in mind. He/she explains that before going further, the meaning of these terms must first be researched (or checked) in documents. He asks the pupils to bring to school any relevant documents they may have.

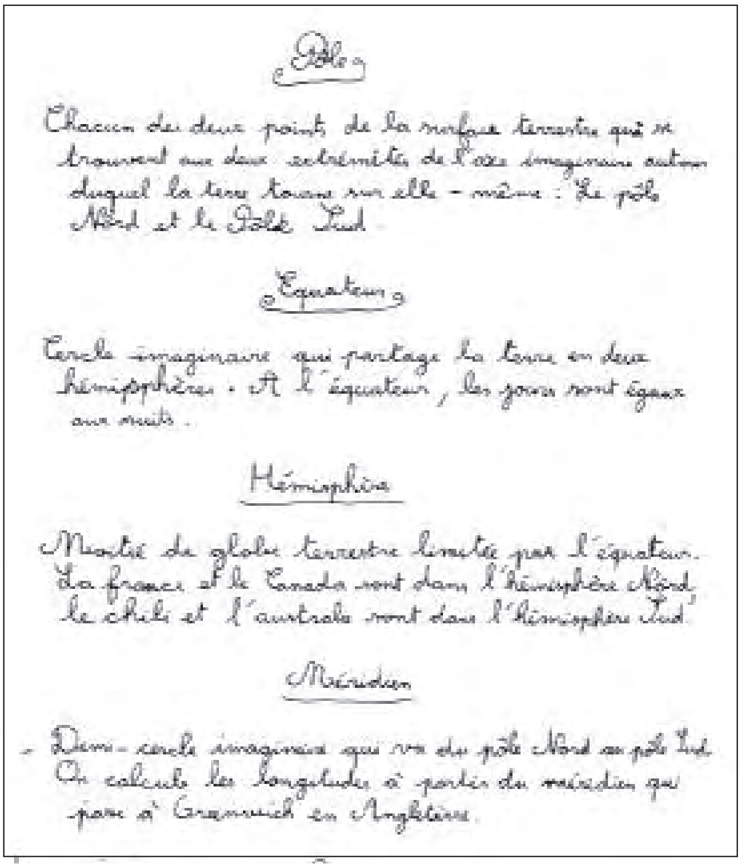
## Lesson 3. Building up of vocabulary (poles, equator, hemispheres, etc.)

Being aware of the need to adopt a precise vocabulary, the pupils undertake documentary research.

**In small groups**
The pupils build up a small vocabulary with the following words: poles, equator, hemispheres, meridian. If necessary they use a simplified drawing to help them. They use various traditional documentary resources (dictionaries, books and journals in the school library, encyclopedias, atlases, world maps and planispheres belonging to the class or loaned by the families) and digital resources (both on- and offline, including keyword search facilities).
- CD ROM:
the Robert Junior 1999 Havas International CD ROM, produced by JERIKO, a teaching aid recognized by the National Ministry of Education:
www.educnet.education.fr/res/bliste.htm
a complete guide to which can found on the CNDP website:
www.cndp.fr/tice/ressources/Le_Robert/present.htm
- Websites:
Useful websites include a `.com' site approved by the Ministry:
www.espace-ecoles.com
Click on `Recherche' [Search] on the home page, where a search with the keyword `méridien' [meridian] gives access to four interesting pages on `the Green Meridian'.

**Collectively**
The teacher checks the definitions found and, where necessary, helps the pupils to understand them, and returns to any difficulties which he/she may have observed. A glossary is created (see Figure 3).

**Individually**
The pupils are reminded of the expressions listed in the previous lesson and asked to replace them by the correct expressions.


Pôle

Chacun des deux points de la surface terrestre qui se trouvent aux deux extrémités de l'axe imaginaire autour duquel la terre tourne sur elle-même : Le pôle Nord et le Pôle Sud

Equateur

Cercle imaginaire qui partage la terre en deux hémisphères. A l'équateur, les jours sont égaux aux nuits.

Hémisphère

Moitié du globe terrestre limitée par l'équateur. La france et le Canada sont dans l'hémisphère Nord le chili et l'australie sont dans l'hémisphère Sud

Méridien

- Demi-cercle imaginaire qui va du pôle Nord au pôle Sud. On calcule les longitudes à partir du méridien qui passe à Greenwich en Angleterre.

*Figure 3*

*"Pole*
Each of the two points of the Earth's surface at the end of the imaginary axis about which the Earth rotates. The North Pole and the South Pole"

*"Equator*
Imaginary circle which divides the Earth into two hemispheres. At the Equator days and nights are equal."

*"Hemisphere*
Half of the globe bounded by the Equator. France and Canada are in the Northern Hemisphere, Chile and Australia are in the Southern Hemisphere."

"*Meridian*
Imaginary semicircle running from the North Pole to the South Pole. Longitude is calculated based on the meridian passing through Greenwich in England."

## Lesson 4. What time is it in Sydney when it is midday in Paris ?

The pupils position the poles on a white ball and trace the Equator and a meridian. After having positioned Paris and Sydney on the ball, they carry out their first simulation.

**Objectives**
To consolidate the definitions found earlier by visualizing them on a white ball representing the Earth (Figure 4, pg. 64). To simulate the position of the Earth facing the Sun when it is midday in Paris (Figure 5, pg. 64) and then when it is midday in Sydney; to understand that it is then night in the other city.

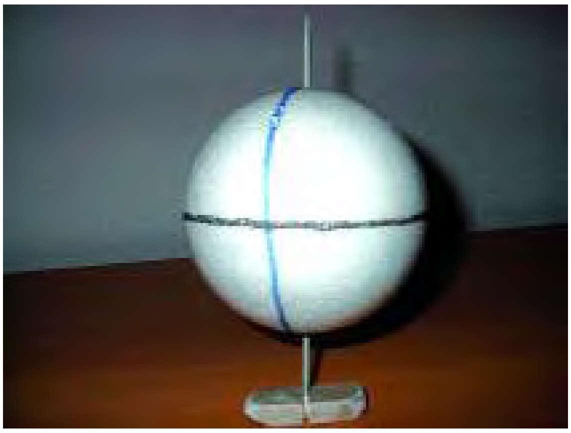


Figure 4


Figure 5

In the photographs presented here (above and on the following pages), the direction of the Sun is perpendicular to the polar axis, something which only occurs at the equinoxes. It is not necessary to bring up this question (outside the programme) with the pupils except if they should themselves object that the duration of the day is not always equal to that of the night (see the section ` To take things further').

**In small groups**
The pupils sketch the Equator and a meridian on their balls using a lead pencil. They position Paris on their balls. Then they attempt to position Sydney with the help of available globes.

Using their ball and a torch, the pupils reproduce the configuration of the initial question[2]. The task is the following: *Place the ball in front of the torch so as to reproduce what happens when it is midday in Paris. Indicate approximately what the time is in Sydney. Draw the experiment.*
The same task is formulated with the situation reversed.

**Collectively**
A larger model is used for a period of summarizing, during which the teacher confirms the explanations proposed by the pupils and returns, if necessary, to the difficulties observed. He/she helps to formulate the conclusion: `The time is not the same in Paris and in Sydney, because when one city is illuminated by the Sun, the other is in shadow'.

At this stage, one might recognize that the pupils' experiments are not very precise. While they manage, in static manner, to place the point representing Paris facing the torch and then to explain that the point representing Sydney is in shadow, the respective movements of the spotlight and the ball are erratic. There is no need to worry about this at the moment.

## Lesson 5. How can one explain the alternation of day and night?

By experimenting with their ball and their light source the pupils try to reproduce the alternation of day and night and imagine various hypotheses.

**Collectively**
The teacher asks the question and ensures that it has been well understood.

**In small groups**
The pupils look for a solution using their model.

[2] The spotlights or torches representing the Sun are directed light sources, although the Sun radiates light in all directions. It is important to ensure that this does not get in the way of the pupils' understanding.

**Collectively**
There follows a recapitulation and a discussion of the various hypotheses. One might, for example, anticipate the following, depending on the pupils' initial knowledge:
- the Earth rotates about its own axis and revolves around the Sun;
- the Earth revolves around the Sun;
- the Earth rotates around its own axis (with no mention of a possible movement around the Sun);
- the Sun revolves around the Earth.

Occasionally, there may be some childish answers: `day time is to work and play in; night time is for sleeping'. These are generally eliminated in the discussions among the pupils. In most cases, the pupils do not manage to manipulate their model in a rigorous manner, which means there is no consensus to determine the hypotheses to be retained or rejected. A second lesson of experimentation with the model will therefore be necessary.

Thus, most often, the lesson ends with the teacher ascertaining that there is a lack of agreement: the class has not managed to agree upon which hypotheses to retain or eliminate. On the other hand, there is a convergence towards a common concern: there is a need to learn how to use the model more rigorously.

## Lesson 6. The alternation of day and night - use of a model

The pupils learn to use the model: as a tool to assist reasoning. They then realize that it does not enable them to distinguish between certain hypotheses. At the end of the lesson, the teacher indicates the right explanation, at the same time noting that it cannot be proved at school.

**Collectively**
The teacher explains the role of the model and how it is used to the pupils. It is a tool which will allow them to reason. The ball represents the Earth, the torch represents the Sun. All observations on the model can be translated into phenomena in reality. For example, if the point representing Paris is in the illuminated area, this translates into reality via the proposition that `it is day time in Paris'; conversely, if the point representing Beijing is in shadow, that translates into `it is night time in Beijing'.

The teacher relaunches work in small groups, with the instructions that each should examine hypotheses, applying this mode of reasoning.

**In small groups**
The pupils start to experiment on the model again. For each hypothesis, they indicate whether or not it is capable of explaining the alternation of day and night.

**Collectively**
Conclusions are drawn. These often disturb the pupils and it falls to the teacher to dispel any remaining doubts. The `right explanation' (the Earth rotates about its own axis) is indicated, noting that the arguments which enabled scientists to establish this cannot be explained to the pupils. Nevertheless, the teacher invites them to think about the general problem of relative movement, making reference to experiences they may have had: a train which starts off gently and makes one think that the landscape is moving in the other direction; a lift. Without undue insistence, a second conclusion may be drawn: one can be moving relative to something without realizing it[3]

[3]The question of relative motion, even rectilinear, is difficult. In the history of thought, it was Galileo who first understood the relativity of motion and described it explicitly.

## Lesson 7. What time is it in Beijing when in it is midday in Paris?

At this stage it is still not possible to answer the question. All one can say is that Beijing is on the boundary between day and night. In order to know whether this is the beginning or the end of the day, one has to know the direction in which the Earth rotates about its axis. The aim of this lesson is to raise this question.

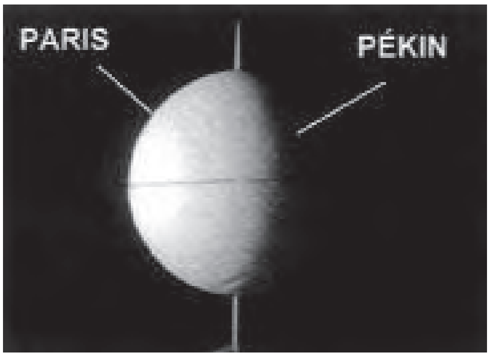
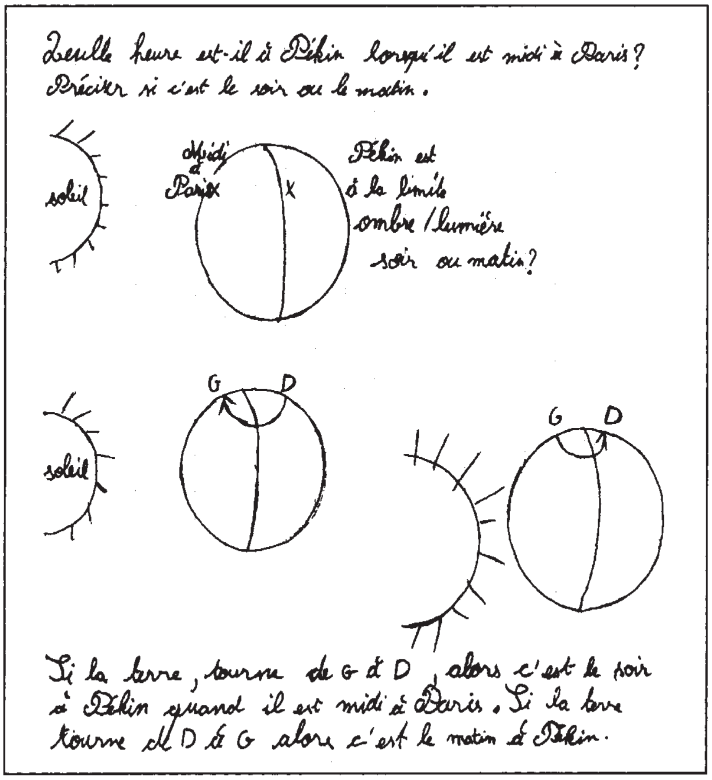



*Figure 6.* If the Earth rotates from left to right (see also Figure 7), then Beijing has just passed into darkness: it is evening in that city. But if the Earth rotates in the other direction, the city of Beijing (Pékin) is about to pass into light: in this case it is morning in that city.

**Collectively**

The teacher recalls the conclusion of the previous lesson and describes the question to which the lesson is devoted. He/she indicates that the answers must be argued through using the usual model and once again goes over how that should be used.




*"What time is it in Beijing when it is midday in Paris?*
*State whether it is evening or morning.*

*Sun*
*Midday in Paris*
*Beijing is on the boundary between shade and light: evening or morning?*

*Sun*
*G=L [LEFT]*
*D=R [RIGHT]*

*If the Earth rotates from L to R, then it is evening in Beijing when it is midday in Paris. If the Earth rotates from R to L then it is morning in Beijing*

*Figure 7*

**In small groups**
The pupils prepare their models by positioning Paris and Beijing.They then experiment and try to agree on the answer to the question asked.

**Collectively**
The different groups indicate the answer which they are thinking of giving to the question. The teacher organizes the discussion. Falling back upon the groups which have understood the problem correctly he/she helps to elicit the conclusion: the question asked cannot be answered without knowing the direction in which the Earth rotates around its own axis.

## Lesson 8. In which direction does the Earth rotate about its own axis ?

Knowing the apparent movement of the Sun, the pupils deduce the direction in which the Earth rotates around its own axis.

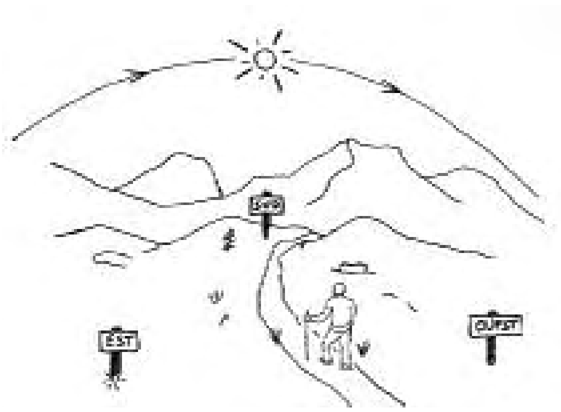



*Figure 8.* From Europe, an observer sees the Sun move from East to West.

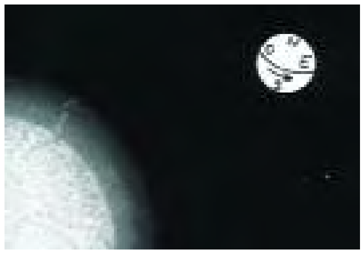


*Figure 9.* From the vicinity of the Sun, a space traveller would see the Earth rotate about its own axis from West to East.

**Collectively**
The teacher recalls the conclusion of the last lesson and the question which remains to be answered. At this stage, it is preferrable to leave the question open, without indicating to the pupils that the key to the enigma is to be found in the apparent movement of the Sun. There will always be time to help them a little later, if they do not make this correlation themselves.

**In small groups**
The pupils seek the answer. They may use their model to help them. The teacher moves around and ensures that the fruitless experimentation does not last too long. He/she provides the help described above when he/she deems it necessary.

**Collectively**
The teacher leads the exchanges between the different groups and confirms the solution. He helps the pupils' understanding by formulating or stimulating the formulation of the following arguments: `If I stand on the Earth, in Europe, and look at the Sun, it moves from East to West during the day, from my left to my right. If I now imagine that I am in the vicinity of the Sun looking at metropolitan France, I see Brittany move to the position where Paris was, that is, from West to East'.

The teacher draws a parallel between these arguments and the situations called up in Lesson 6 (trains, lift) by and has the pupils draw the corresponding diagram. He may help them to conclude the following: `We cannot decide in a definitive way which object (Earth or Sun) is moving, but we have at least established that if the Earth rotates around its own axis, then it does so from West to East'.

# Lesson 9. What time is it in Beijing... ?

The pupils now have all the elements needed to understand the principle of time zones. They return to the question left in suspense in Lesson 7. They then deal with other examples.

**Collectively**

The teacher recalls, on the one hand, the unresolved question, namely `when it is midday in Paris, what time is it in Beijing?', and, on the other hand, the question of the direction in which the Earth rotates about its own axis. He/she uses a globe to explain the meaning of the expression `from West to East', which is usually employed to describe the direction of the Earth's rotation. On his/her desk, he/she places a model which may serve to help the pupils.

**Individually**

The pupils seek the answer to the question and formulate it in writing. Correction is undertaken collectively.

**Collectively**

It is now a matter of applying what the pupils have just understood about Paris and Beijing to other cities.

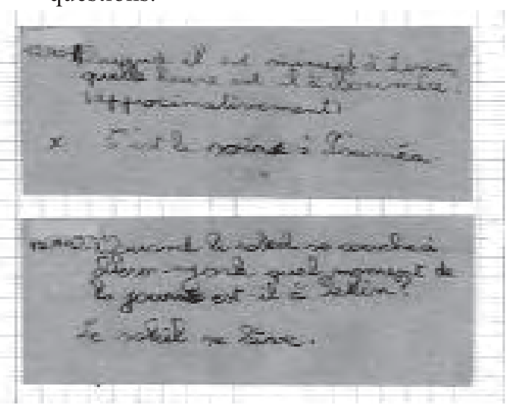
For simplicity, we suggest cities which lie on approximately the same meridian (New York and Lima) or on meridians which make an angle of approximately $90^{o}$ with one another (Paris, Beijing, Sydney, Lima and New York). In this way, the difficulty of the exercises may remain limited, with the questions (whence also the answers) being restricted to four particular times of day: midday, midnight, the start of the night and the end of the night.

Thus, the teacher asks the pupils to find out where these three new cities are located and to position them on their ball. He/she explains that they will then have to use the model to answer the questions written on the board:

`It is midday in Lima, what is the time of day in Sydney?'
`The sun is rising in Beijing, what is the time of day in Paris?'
`Night is falling in New York, what is the time of day in Lima?', etc.

**In small groups**

The pupils position the cities suggested on their ball, with the help of atlases and globes. They then attempt to answer the questions. When they agree amongst themselves, they invent and ask new questions.



*"When it is midnight in Lima, what is the time of day in Noumea (approximately) ?
It is evening in Korea"*

*"When the Sun is setting in New York, what is the time of day in Beijing ?
The Sun is rising"*

*Figure 10*

During the first phase, the pupils pass between a planar and a spherical representation of the Earth. The exercise is particularly educational and sufficient time should be allowed for it.

**Collectively**

The teacher corrects the questions which he/she set. He/she picks up a number of examples which he/she knows may cause problems. In particular, he writes two sentences on the board:`The time is not the same in Paris and Sydney because Paris and Sydney are not in the same hemisphere' `The time is the same in New York, which is in the Northern hemisphere, and in Lima, which is in the Southern Hemisphere'.

The pupils write down, individually, on their slates, whether each statement is true or false. The first statement is corrected and becomes: `The time is not the same in Paris and Sydney because Paris and Sydney are not on the same meridian'.

## Lesson 10. How can we record what we have learnt ?

Several activities are proposed. The aim is to represent the Earth\Sun system, viewed from the North Pole, in a planar space, in such a way that the different times of day (midday, midnight, afternoon, start of night, end of night) are taken into account.

**Activity 1**
The teacher presents the photographs of Annex 2 which he/she has reproduced. Working individually, the pupils indicate the time of day in each city. They then form small groups and compare their results. They use the model if they need to.

**Activity 2**
This involves building the model shown in Figure 11 (the circle representing the Earth is free to move around a paper fastener, it may be large in size to facilitate observation by the pupils), and then to set it working, always based on questions: `It is afternoon in Beijing, what is the time of day in Los Angeles?', etc.
If necessary, the model can be improved by dividing the moving circle into 24 sectors, representing the 24 time zones.


"La Terre = *Earth*
Après-Midi = *Afternoon*
Midi = *Midday*
Matin = *Morning*
Fin de nuit = *End of night*
Minuit = *Midnight*
Début de nuit = *Start of night*
Le Soleil = *Sun*
(très loin) = (*very far away*)"

*Figure 11*

**Activity 3**
We come to the classical representation. The pupils have to add labels to the diagram of Figure 12 (magnified).

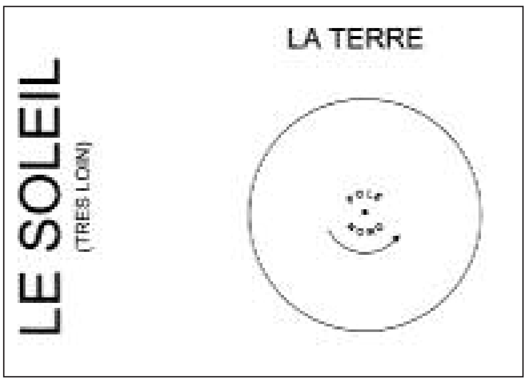



*Figure 12.* Add a label, indicating the zone where it is:
- midday;
- midnight;
- the start of the night;
- the end of the night;
- the morning;
- the afternoon..

## Conditions for the teaching of the module

### Materials for a group of pupils

- A map of the time zones (see Annex);
- a torch to represent the Sun;
- a small ball (polystyrene, for example), pierced from one side to the other by an axis (knitting needle, meat skewer...) , to represent the Earth. The size of the ball representing the Earth should be commensurate with the width of the beam from the light source so that it lies largely within that. To avoid risks of injury, the teacher himself/herself creates the polar axis by inserting the needle along a diameter of the ball.

### Materials for use when summarizing

- A white ball to represent the Earth, larger than those used by the pupils;
- to represent the Sun, a spotlight or a relatively powerful light bulb (100 W)[4]. If this latter solution is chosen, care must be taken regarding the safety of the device, which should not be touched by the pupils.
- It is also useful to have a number of globes.

### Duration

Some ten lessons of 45 to 60 minutes each seem to be needed. The procedure is this quite long, but an important part of the astronomy programme is also dealt with at the same time as geographical concepts.

### Recommended fact sheets

See essentially sheet no. 20, `Rotation of the Earth about its own axis'. As a supplement, for preparatory activities, it may be useful to refer to sheet no. 19, `Apparent movement of the Sun' and to sheet no. 21, `The Solar System and the Universe'.

## Conclusion

The main areas of knowledge targeted by the various lessons are those prescribed in the official programmes which we referred to in the Table `Position in the programmes'. They essentially concern astronomy, but also geography, in a subsidiary manner.

Beyond these areas of knowledge, the pupils were involved in activities which allowed them to reflect on the different viewpoints which can be taken to explain a single phenomenon. By endeavouring to determine a coherence between the phenomena observed and described from a terrestrial (East, West) and an egocentric (left, right) position and an abstract representation (model, diagram) the pupils learn to move off centre and thus develop their ability to find their bearings in space.

If the opportunity arises, work relating to the Moon will permit new experimentation with models and allow one to evaluate the extent to which the skills associated with their use and the mental picture of space have been brought to bear.

Finally, throughout the procedure, the pupils are invited to engage in reflection, exchanges and reasoning. They have to express their ideas or their explanations in writing using text and diagrams. The forms and styles of these written productions are varied (collective posters, written work by individuals or by small groups, glossary,...). All these elements contribute to a progression in their mastery of the language.

[4] A good contrast can be obtained using a 100 W bulb, but this dazzles the pupils. This disadvantage can be avoided by placing a sheet of cardboard between the bulb and the class.

## To take things further

The need for a universal time can be touched upon as an extension[5]. It is useful to have a common time everywhere in the World in order to date events of world importance (on which day and at what time did Neil Armstrong set foot upon the Moon?). The time of our time zone (which is also that of Greenwich) is used for this time, which is known as universal time (UT).

At the end of these lessons, the pupils have, on the one hand, associated time with the apparent movement of the Sun and, on the other hand, experimented with balls and spotlights to model the phenomena; this may lead the pupils to ask numerous pertinent questions which are not easy to answer. `Why is the shadow of a sundial not shortest at midday on our watches?' `Why is the length of the day not always equal to that of the night?' `What is the dateline?', etc. The teacher may help the pupils to come up with some elements of the answers. But he/she is not obliged to do so. For a sequence of scientific activities to end with new unresolved questions is not only possible but also desirable. Moreover, this happens in scientific activity proper. With a view to helping the pupils to take an even more lateral view, it is interesting, during work on the Moon or the Solar System, to refer to the alternation of day and night on other stars: *viewed from the Sun, the planet Jupiter rotates around its own axis in approximately 10 hours. How long is the Jovian night? How long is the afternoon? Viewed from the Sun, the Moon rotates around its own axis in approximately 30 days. How long is the Lunar night? In* Le Petit Prince *there is a lamplighter who lives on an imaginary planet. He lights and extinguishes his lamp once a minute. How long does it take, for this imaginary planet, viewed from its star, to perform a complete rotation around its own axis? How long is its day, and how long is its night?*

Finally, one might ask the pupils to carry out documentary work on Internet sites. Taking into account trials we have performed, we find it preferable to have the pupils work from a prepared list[6]:

- draw up a list of institutions such as CNRS, CEA, NASA, etc., giving the meaning of all these acronyms;
- produce a list of ten sites, classified by order or relevance; this list contains the following:

? a category of institutional sites of varying quality for each subject, where the pupils are to identify the best ones;

? a category of interesting non-institutional sites (well documented personal pages)

? a rubbish category (sites bearing little or no relation to the subject).

- Finally, the pupils could be assigned to real research, using a search engine and well chosen keywords.

## Tentative selection of sites

www.fourmilab.ch/earthview/
Very good site (in English), with interactive images of the planet with variable illumination for day and night.

www.obs.univ-lyon1.fr/-ga/terre.html
Animation of the rotating Earth

http://195.221.249.130/Pointeurs/liens-img/science.htm
Bank of scientific images. Choose the image of `the Earth at night'. This image shows the impact of nocturnal illumination; some continents are lit, others are weakly visible: access to electricity leads to a strong disparity.

www.bips.cndp.fr
The previous site was an extract from this bank of images, which it is useful to know about because of its applicability to all disciplines.

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[5]This topic does not appear explicitly in the programmes but can, nevertheless be studied if the teacher feels able to teach it properly.

[6]Using the search engine www.google.com with the classical keyword `day + night alternation' or `day+night+planet Earth' one finds more than 800 site references.

www.ac-nice.fr/clea/C1.html
A rigorous presentation for teachers concerning the measurement of time and geographical coordinates.

www.planetobserver.com/commun/jsp/navigateur?espace=Ind&langue=fr
Click on `naviguez' [navigate] to obtain a high-definition image of the Earth which can be observed in different perspectives (polar views, for example)

www.ac-poitiers.fr/pedago/ecoles/cederom-ien/former/ressourc/monde.htm
Bank of scientific images; many documents in `Earth observation'.

www.teteamodeler.com/boiteaoutils/decouvrirlemonde/fiche29.htm
This page of the site contains beautiful images of the Earth in different phases of the day or of the night (click to display them on a full screen) together with an activity sheet `produce a mini Earth'.

www.inrp.fr/lamap/scientifique/astronomie/consultants/reponses_consultants.htm
The *La main à la pâte* site invites teachers to ask questions in astronomy to which scientific consultants reply in a simple and precise way. Questions and answers are archived.

www.geocities.com/heureinternational/
This site presents conversions between universal time (Greenwich meridian) and local time in tabular form. It is interesting to confront the pupils with two types of presentation: the table and a time-zone map.

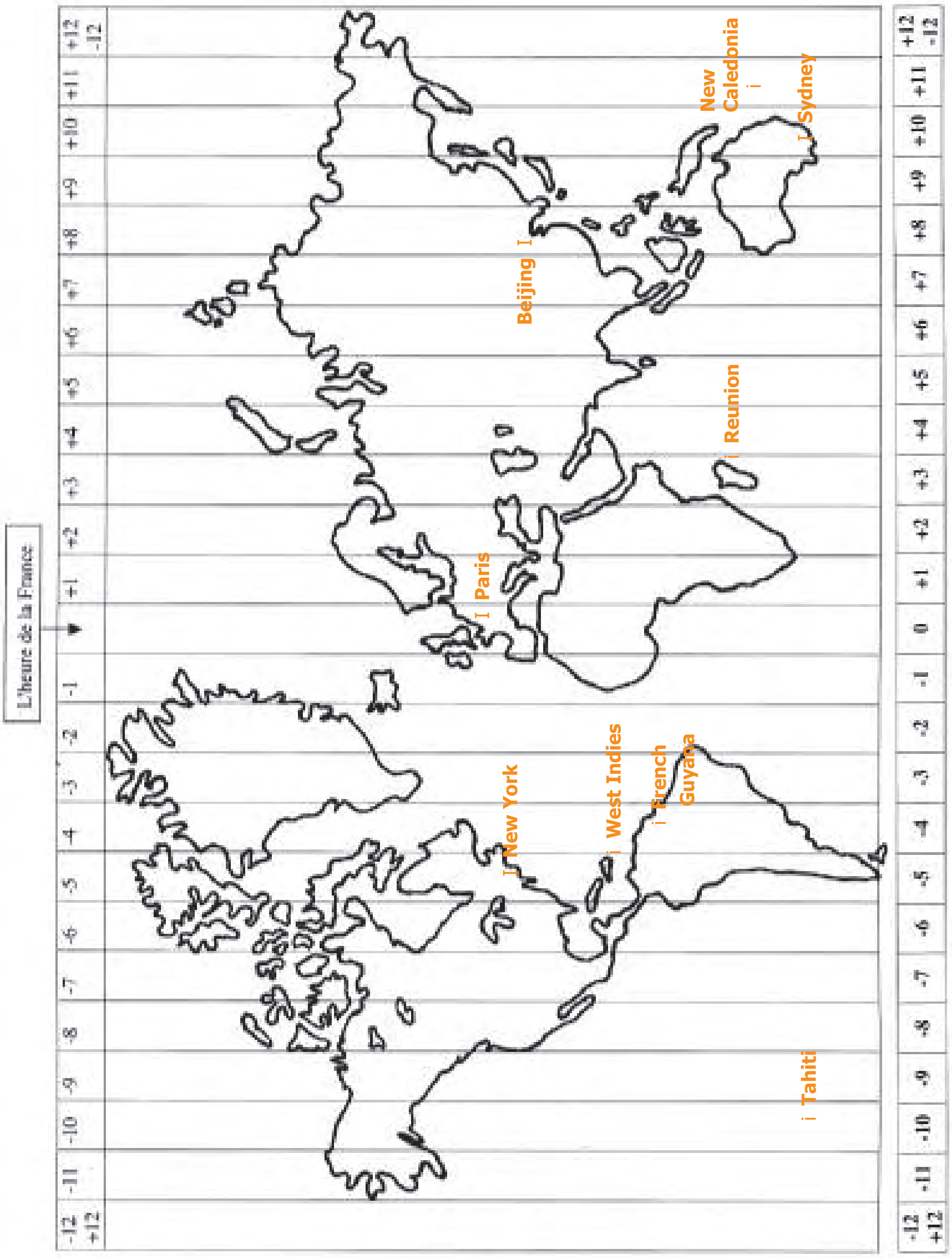
http://fgi.citeglobe.com/fuseaux/fuseaux.html
World time-zone map
www.rog.nmm.ac.uk
Site in English. By clicking on *Home of the prime meridan of the world* the teacher gains a better understanding of the position of  the zero meridian.

www.ens-lyon.fr/RELIE/Cadrans/
Presents both scientific explanations and teaching suggestions concerning sundials.

## Sources

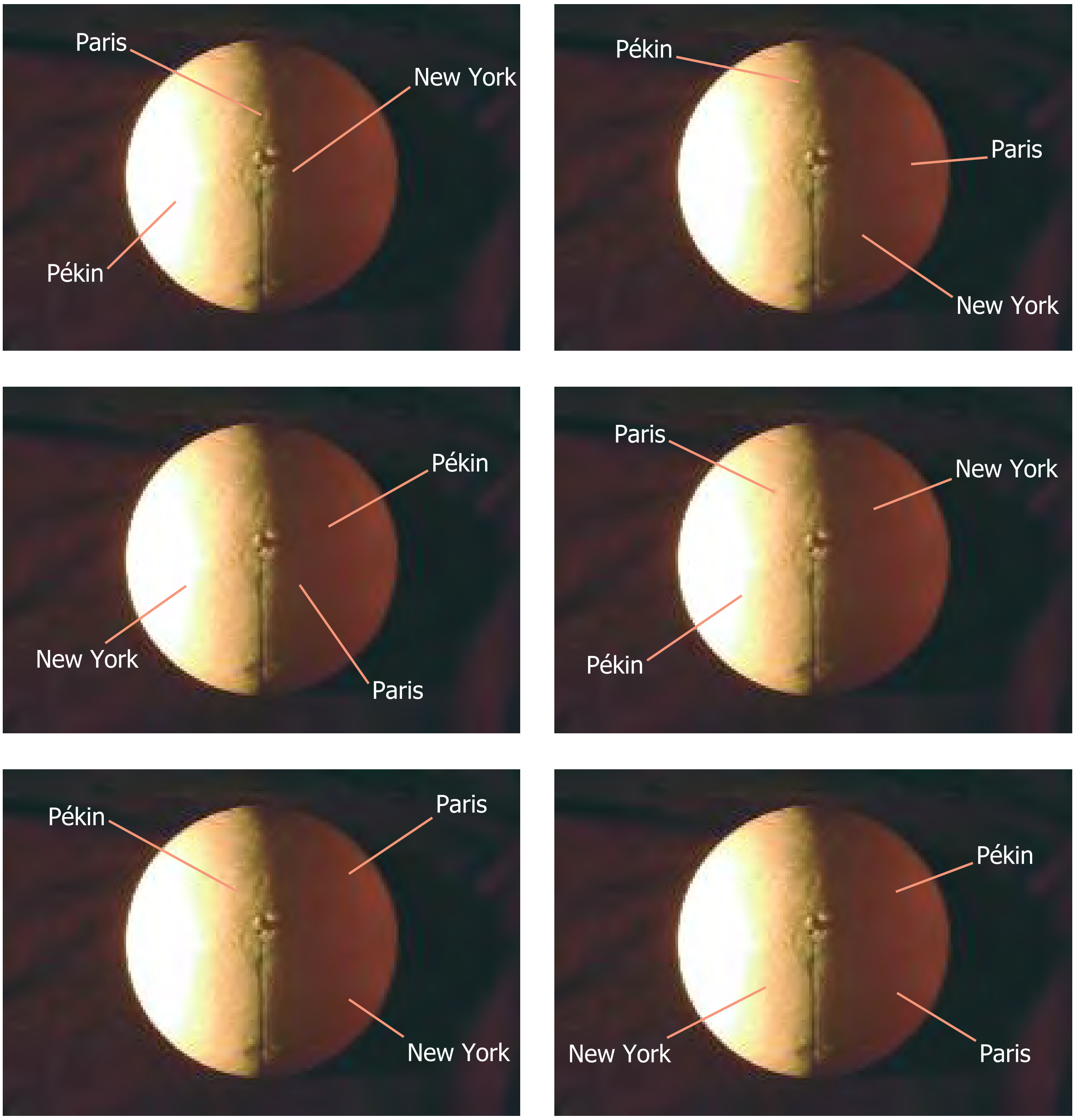
Work trialled in the CM1 class of the elementary school  of Beaupré-Le-Châble (74) and in the CE2-CM1-CM2 class of the Le Chaumet school in Évires (74) where the pupil documents were produced.

## Frieze to be used in Lesson 1 and when summarizing




The frieze on the right should be cut out (and the two sides extended by a few hours). It can then be superimposed on the map, with any time zone used for reference (the zero). This immediately gives the time difference between any reference city and any time zone. This frieze should be used at the end of the first lesson to help pupils who have difficulties, and then when summarizing.

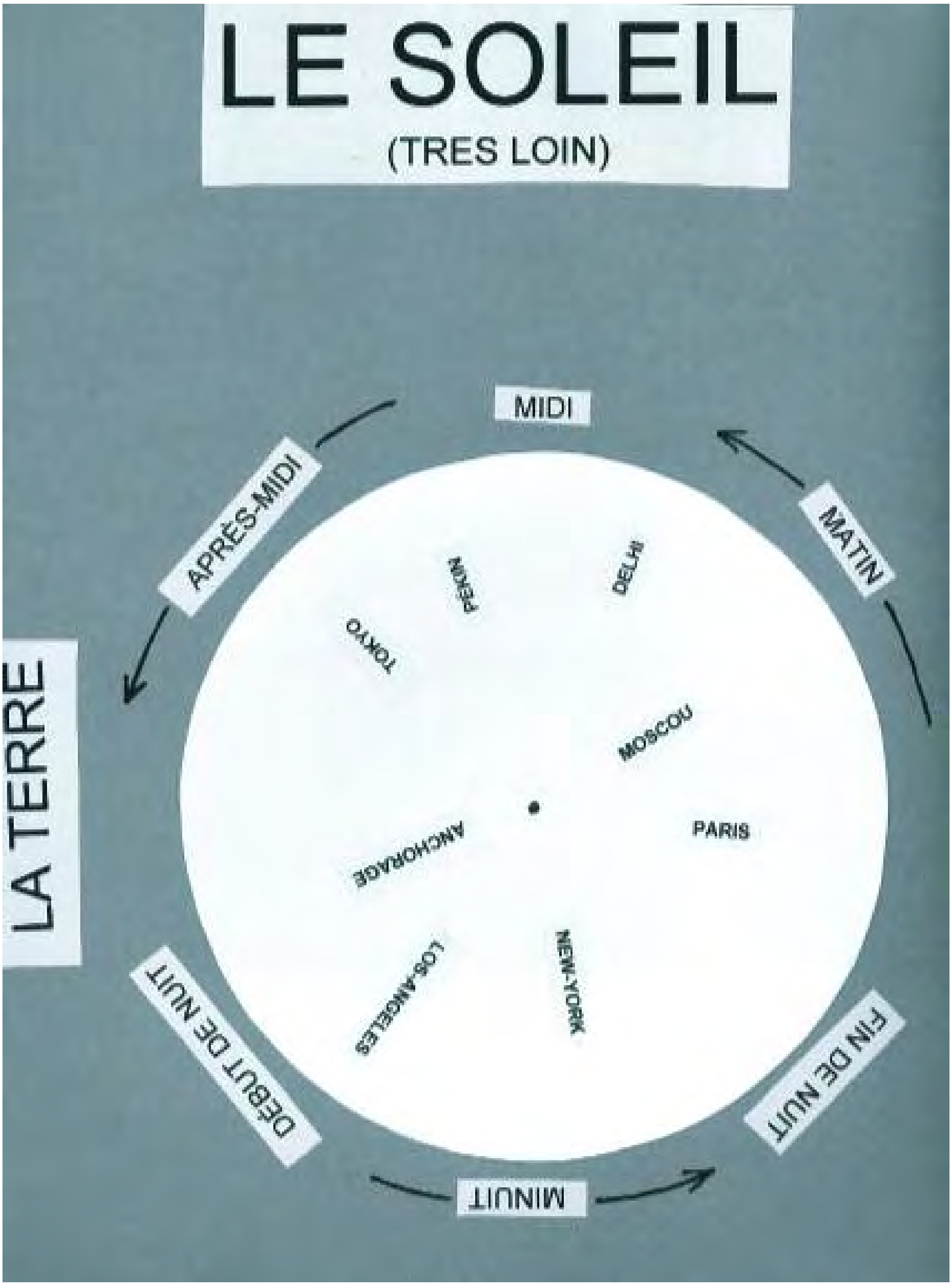
## Photographs to be used in Lesson 10




*[Pékin = Beijing]*

Photographs to photocopy and cut out. For each of these, the pupils try to determine the time of day in each city. The teacher may remind them of the direction in which the Earth rotates about its own axis.

## A cardboard model to be built



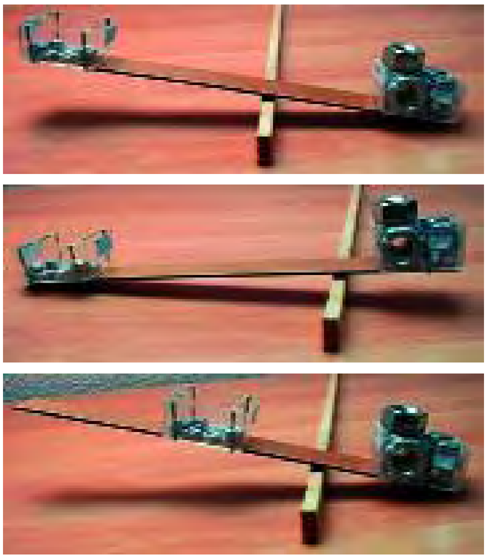

*" Le Soleil (très loin) = Sun (very far away) | La Terre = Earth | Midi = Midday | Matin = Morning Fin de Nuit = End of night | Minuit = Midnight | Début de Nuit = Start of night | Après-Midi = Afternoon | Moscou = Moscow | Pékin = Beijing"*

An example which can be built by pupils.

# How the lever works -

# "Give me a fulcrum : I will lift up the World"

This module describes educational activities designed to show that the efficiency with which a solid body is made to rotate by a force of a given magnitude is more or less proportional to the distance between the axis of rotation and the position at which the force is applied. The study begins with a special object, the lever. The latter consists of a rigid bar which can move about an axis of rotation, called the pivot (or, formerly, the `fulcrum'). A lever modifies the force to be applied. This module also goes beyond the immediate subject matter to show that the same principle is at work in other machinical constructions. We have chosen the drawbridge, which is not a lever in in the strict sense, although its operation is based upon the same principle. A lesson is also given over to the recognition of the lever principle in living organisms. Through these examples, we shall seek to illustrate the interest and complementarity of approaches having their roots in different disciplines: search for a general principle applicable in different contexts (mechanical constructions, living world); constructions; search for a technical solution; study of mechanisms.
For example, in order to lift a given object, is it possible, in the limit, to use as small a force as one wishes, provided one uses a sufficiently large lever? In the Third Century BC, Archimedes said `Give me a place to stand and with a lever I will move the whole World'. However, to counterbalance, we note that the object will be raised to a lesser height. This last aspect, which is completely general, is of great theoretical importance, since it is related to the principle of the conservation of energy.



In this configuration, the load (five large nuts in the box on the right) cannot be lifted by the force due to the six small nuts located in the box on the left.

If the pivot is moved away from the load, it then becomes possible to lift the latter.

If the force due to the box on the left is exerted too close to the pivot, it can no longer lift the load.

*Figure 1.* The lever principle

## Position in the programmes

| Extracts from the programme | Extracts from the application document | |
|---|---|---|
| | **Specific skills** | **Remarks** |
| **World constructed by man**<br>- Levers and scales | Ability to anticipate or qualitatively interpret certain equilibrium situations, in particular when the forces which are applied are not equally distant from the axis.<br>Ability to use the following two properties to achieve the above:<br>- the same force has a greater effect on the rotation if it is applied at a greater distance from the axis;<br>- a large force has a greater effect than a small force applied at the same distance from the axis. | Efficient concrete instances form the basis for the pupils' (purely quantitative) reflection. Possible examples: construction of a crane and balancing of the jib; production and equilibrium of a mobile; manufacture or use of pliers, of levers.... Study of their effectiveness. |
| **The human body and health education**<br>- Bodily movements (operation of joints and muscles) | Ability to establish relationships by comparing with observation of the feet of animals.<br>Ability to make use of X-rays photographs or multimedia documents.<br>Ability to design and build a simple physical model taking into account the role of antagonist muscles in the movement of a joint in an approximate way. | This study (...) involves activities which will enable the pupils to question their ideas by building up their personal functional view of movement. Only very simple modelling will be undertaken. |

The principles governing the equilibrium of a solid body capable of turning around a fixed axis are not touched upon in the current secondary school programme.

### Knowledge and know-how which it is desirable for pupils to acquire or be acquiring at the end of the module

- To be able to recognize the lever principle in different areas and to identify the axis around which the rotation takes place (pivot).
- To know that the effectiveness of an applied force is greater when it is applied at a greater distance from the pivot and that this principle was used by men to build the first machines.
- To be able to describe the principle of the latter using a simple model
- To be able to describe the operation of a system involving articulation (a joint) using a simple model. This last skill cannot be acquired at the end of this module alone (see the construction of a weather vane in the module `How do we know where the wind comes from?'), although this module will contribute towards that skill.

## One possible way in which the module might be taught

The first two lessons introduce the idea of the lever based on a situation experienced (lifting up the teacher's desk) and reference to constructions created by man before the invention of motorized machines (for example, the Egyptian pyramids). The next two lessons are devoted to a more precise qualitative study of the lever principle. Lessons 5 to 7 study levers in another context, that of drawbridges. Lesson 8 provides an awareness of the presence of levers in living organisms. It is more difficult to access and is only intended as a possible extension.

| Lessons | Starting question | Activities undertaken with the pupils | Conclusion from the lesson, outcome |
|---|---|---|---|
| Lesson 1<br><br>Lesson 2 | How to lift the teacher's desk<br><br>How did people lift loads in Ancient Times? | Search for hypotheses in an open context<br><br>Construction of a model from a picture of an ancient machine | Classification in two columns: motorized machines or machines using human force<br><br>Introduction of the idea of the lever |
| Lessons 3 and 4 | How can the effort be reduced using a lever? | Experimental exploration of the lever principle | When the load is near the pivot, less force is needed to lift it, but it is lifted less high.<br>When the load is further from the pivot, more force is needed to lift it, but it is lifted higher. |
| Lesson 5 | How to make a model of a drawbridge | Construction using modular material | The lever principle is implemented by the pupils in another context, but not necessarily in a conscious manner |
| Lesson 6 | Where should the wire be attached to the bridge? | Experimentation | When the wire is attached far from the axis it is easier to lift the bridge. |
| Lesson 7 | What is the same, what is not the same? | Search for differences and similarities in two situations involving levers | Abstraction of a common principle and definitive formulation of simple, but general, rules |
| Lesson 8 | Are there levers in living organisms? | Application of what has been learnt, reasoning | The position where muscles are attached is crucial to movement in a jointed system. |

# Lesson 1. How to lift the teacher's desk

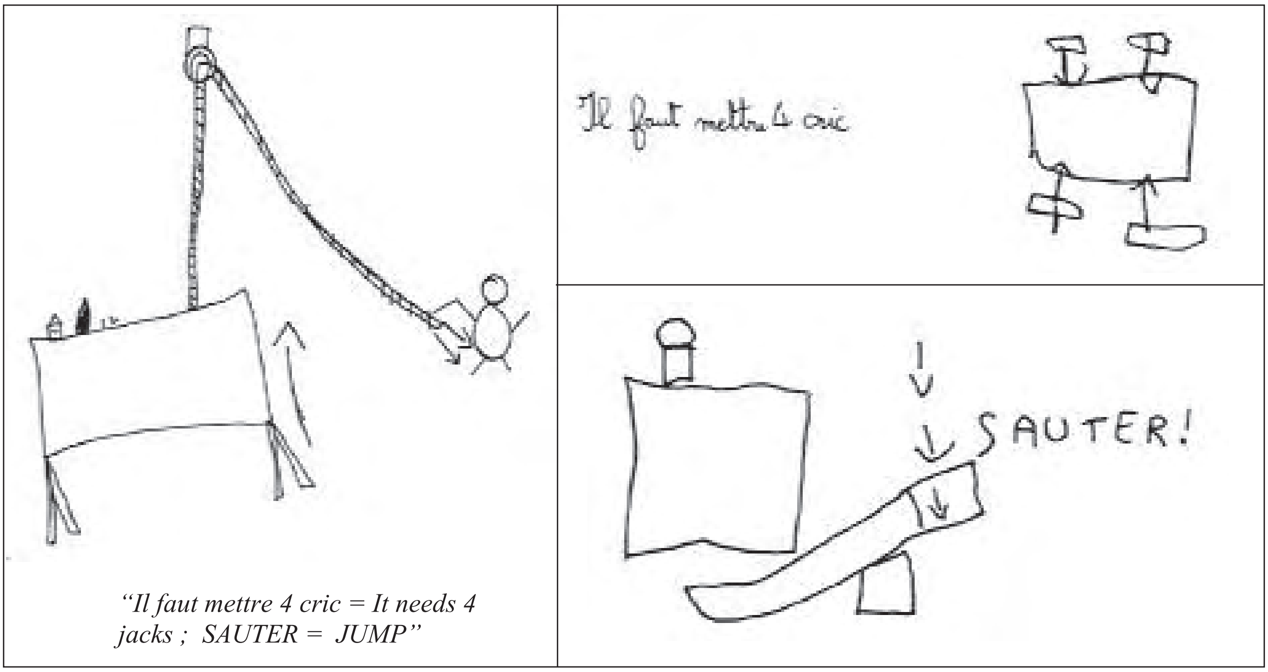
The pupils are asked to think about ways to lift a heavy object, the teacher's desk. This leads to a classification into two categories: systems which use human or animal energy and those which use a different kind of energy.

### Collectively

The teacher may talk about the dramatic consequences of floods and the need to lift furniture to protect it from water damage. He/she then lays down the challenge: lift the desk in order to insert wedges under its feet.
One or two pupils should be allowed to test the operation on their own and their impressions should be recorded: “It's heavy”; “It hurts your hands and your back”, “I don't have the muscles, the strength...”.
Hence the problem: think of how the task could be made easier so as to complete the challenge.

### In small groups

The pupils think up plans of action. They describe them in writing or drawings in their experimental notebooks (Figure 4).
Some ideas:
- several people might work together;
- the tasks could be shared: two pupils would lift the desk while another slid in the wedges;
- a hook could be attached to the ceiling and the desk lifted with a chain;
- one could use a crane, a helicopter, a jack...;
- one might place a plank under the desk with a brick underneath it and jump!




*“Il faut mettre 4 cric = It needs 4 jacks ;  SAUTER =  JUMP”*

*Figure 4*

### Collective summary

Each group presents its ideas. These are classified in a table with two columns: devices moved by people and those which operate in a different way.
The teacher ends the lesson by telling the pupils that the module will concentrate throughout on plans of action  of the type listed in the first column.
N.B. At this stage, the teacher is not seeking to introduce the idea of the lever come what may. If it is suggested it is classified with the other schemes in the first column.

## Lesson 2. How did people lift loads in Ancient Times ?

The pupils build machines based on levers starting from pictures of devices used in Antiquity. The lesson ends with a first formulation of what a lever is.
N.B. It will be convenient to have boxes of building materials available. If this is impossible, wooden rods and string will suffice.

**Collectively**
The teacher talks about a number of constructions built since the dawn of humanity before motorized machines existed. He/she may refer to the building of the pyramids, presenting a number of pictures or photographs and talking about the air of mystery which still shrouds the techniques used given the enormity of the masses that had to be lifted[1].

**In small groups**
The teacher distributes the sketches of figures 5 and 6, which show two schemes for lifting or moving stone blocks[2]. The pupils build a reduced model of the machine shown in Figure 5. In turn, they come to the desk to try out the solution of Figure 6, under the supervision of the teacher who oversees the safety aspects.

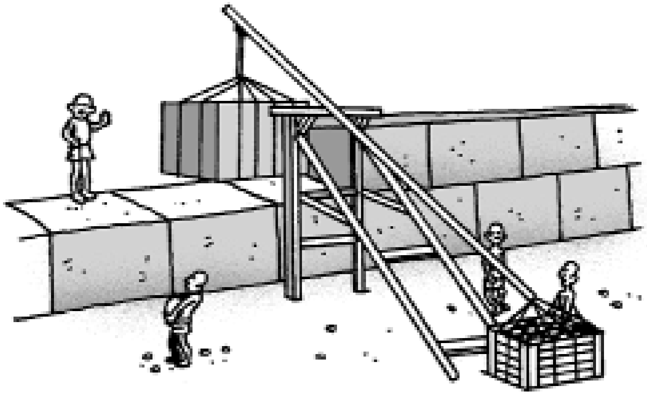


*Figure 5*. © SEAMEO RECSAM, Penang, 2007

**Collectively**
The teacher directs the class towards the following question: do these schemes lead to a reduction in the effort needed? A positive answer can be given in the case of the scheme of Figure 6 which has been tested. On the other hand, the model of Figure 5 does not necessarily provide an answer: the excitement of building it and playing often predominates over the precise study of the effort that needs to be applied, which is premature at this stage.

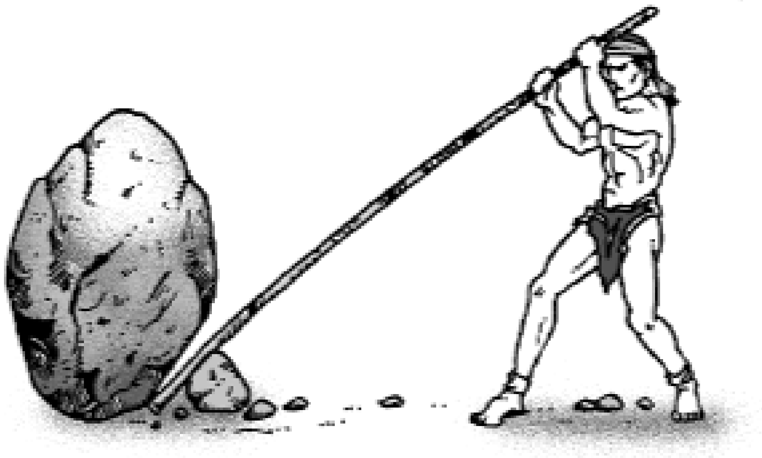


*Figure 6*. © SEAMEO RECSAM, Penang, 2007

[1]There are two main hypotheses: slow progression on gently inclined ramps and the use of machines based on the lever principle. Both still raise problems for historians. For a possible pedagogical exploitation, see the section `To take things further' at the end of the module.
[2]If the teacher wishes to devote more time to this module, he/she may ask the pupils to look for information on this question themselves and to bring any interesting documents they find into class.

We are not seeking to draw conclusions but simply to formulate the question and commit it to memory. The word `lever' is introduced based on an examination of what the two sketches of Figures 5 and 6 have in common.
The pupils are encouraged to develop a first formulation which will be enriched over the course of the lessons. Strong ideas, at this stage in the module include the following: a lever is a rigid rod which can swivel around an axis of rotation (the pivot); it is manoeuvred by man to lift loads.

## Lesson 3. How can the effort be reduced using a lever?

The pupils understand that a lever can be used to reduce the effort provided that the relevant quantities are acted upon.

### Material

- For the pupils:
A box containing 10 identical masses (represented here by nuts) is attached to one end of a ruler of length approximately 30 cm (see Figure 7). It symbolizes the load to be lifted. A second box and the elastic band used to attach it are also prepared, but the box is not attached to the ruler: it will be up to the pupils to do this and to test the effect of the distance from the pivot.
- For the teacher:
Longer rulers and rods to be offered to groups which have completed their first exploration.

*Figure 7*

### Collectively

The teacher explains to the pupils that they are going to work on levers resembling the one in the model they have just built (Figure 5), albeit simpler, more practical and more robust. He/she presents the material (Figure 7). The picture to be painted is that of a miniature world in which the small people are unable to lift more than one nut at once. Using the material provided, they have to manage to lift a box containing 10 nuts. The instructions are initially open. The teacher ensures that the pupils have a correct perception of the correspondence between the elements of Figure 5 (sketch of the real machine) and those of Figure 7 (model).

### In small groups

The pupils carry out their first experiments using extra nuts which they place in the second box. They are encouraged to try a number of different approaches by leading questions:
- “Can you manage to do it using fewer nuts?”
- “Can you lift the load higher?”
- “Where did you attach the second box? Did you try to attach it closer or further away?”

He/she gives the fastest groups the second 50 cm ruler.
“Try with the other ruler. What does that change?”

It is important that, the pupils should experience the influence of different parameters (position of the pivot, position of the box containing the nuts they add, length of the rulers) and their consequences (increase or reduction in the number of nuts needed, height raised) in the course of the experiments they undertake.

### Collectively: sharing of findings

The aim of this last phase is to share the different observations performed. A summary, which will end with the identification of a number of rules governing the lever principle, will be made at the end of the next lesson, after further experiments.

## Lesson 4. How can the effort be reduced using a lever?

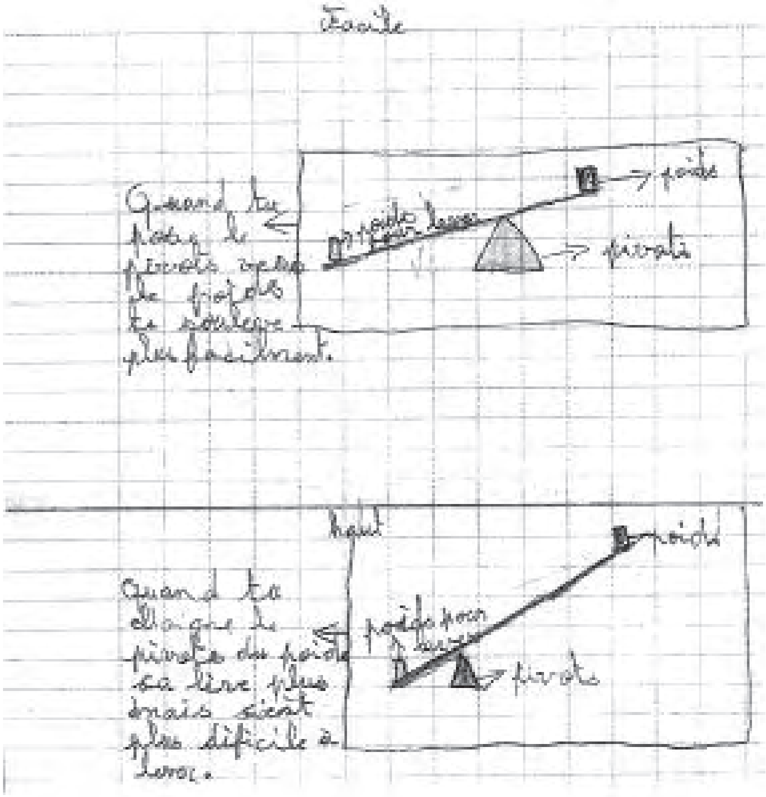
The pupils systematize the observations of the previous lesson upon which a structure is placed, during the summarizing, using a number of simple rules which enrich the concept of the lever.

**Material**
This is identical to that of the previous lesson. We note that the pivot is a ruler or a rod with a triangular cross section. This is important if we are to solve problem 1 (see below) correctly.

**Collectively**
The pupils are faced with three problems:
- How many nuts are needed to lift the box containing 10 nuts when the pivot is in the middle?
- What is the smallest number of nuts needed to lift the box of 10 nuts?
- What is the maximum height to which the box containing the 10 nuts can be lifted? How many nuts have been used?

**In small groups**
The pupils experiment and agree on the best solution they can think of to solve each problem.

**Individually**
The pupils produce a drawing which explains in each case where the group placed the pivot and the height to which the box containing the 10 nuts was lifted.



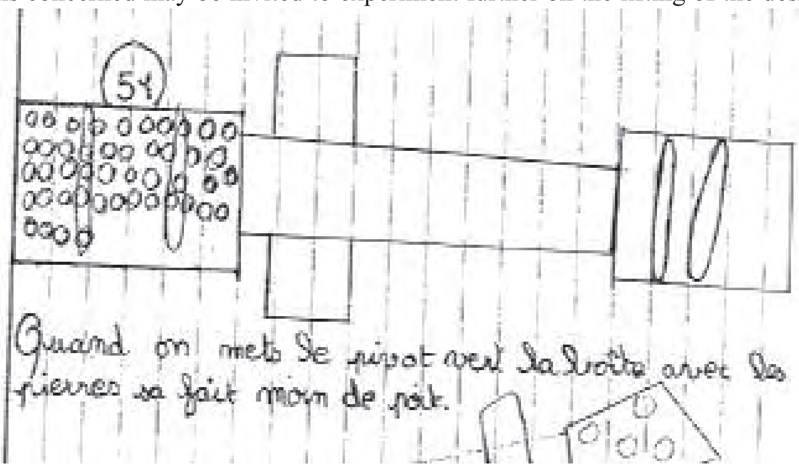

*"When you put the pivot near the weight you can lift it more easily."*
-----------------------------
*"When you move the pivot further away, you can lift it higher, but it is more difficult to lift."*

*Figure 8*

**Collective summary**
This is essentially based on the pupils' experiments. To supplement the pupils' experiments, the teacher may find it advantageous to set up an experimental device which can be seen by the whole class: a solid plank of length approximately 2 m, resting on a log. Under the teacher's direction, two pupils of different builds take up position on this see-saw. The demonstration helps to illustrate the second and third rules below:
- When the pivot is in the middle of the lever, the latter is in equilibrium; the loads are identical.
- The nearer the load is to the pivot, the easier it is to lift it, and it is lifted to a lesser height.
- The further the load is from the pivot, the more difficult it is to lift, and the higher it is lifted.
These rules enrich the concept of the lever which was given an initial formulation in lesson 2.
To end, it is interesting to discuss Archimedes' famous phrase `Give me a place to stand and with a lever I will move the whole World' and its practical limits (length of the lever and solidity of the material comprising it).

### Possible difficulty

Some pupils think that when the pivot is moved away from the load the latter becomes less heavy (Figure 9). The pupils concerned may be invited to experiment further on the lifting of the desk (as in Lesson 2) by acting close to the pivot and then further away. They should realize that they are not stronger in the one case than in the other, but that the task is easier. Work on the see-saw may also be beneficial.




*"When the pivot is placed near the box with the stones it is lighter."* Figure 9

## Lesson 5. How to make a model of a drawbridge[3]

The pupils have been initiated into the lever principle by carrying out activities in a particular context. Here, they apply their knowledge in a different context.

### Collectively

N.B. In cycle 3, the pupils have already taken an interest in fortified castles (at school or at home). Their ideas about drawbridges are already sufficient to embark upon the work.

The teacher presents the activity: to build a drawbridge, like in a fortified castle. He/she does not tell the pupils that this is an extension of the study of levers. If they realize this themselves they must then be encouraged to follow up their idea and asked about the similarities they see between a drawbridge and a lever. However, in our opinion, it will only be possible to explain this to the majority of the class in Lesson 7.

### In small groups

The pupils carry out their building work according to their own understanding. The teacher helps them to solve minor technical difficulties: the production of the bridge and the implementation of a mechanism which allows it to rotate, guides for the wire, solidity of the pillars, etc. However, he/she does not become involve in the choice of the point at which the wire is attached to the bridge frame. A picture of a drawbridge may be shown to any groups which experience difficulties.

*Figure 10.* A drawbridge
© SEAMEO RECSAM, Penang, 2007

[3]This lesson is easier to organize if boxes of building materials are available to the teacher.

### Collectively: summary

The various groups present their models, and explain the difficulties encountered and how they were resolved. It is not certain that all the groups will finish within a single lesson. The teacher will decide whether to suggest an additional lesson or whether to release a short time between this lesson and the next one so that all the pupils can complete their construction.

## Lesson 6. Where should the wire be attached to the bridge?

The pupils think up and perform an experiment intended to show that it is easier to lift the bridge when the wires are attached far from the axis of rotation.

### Collectively

The teacher has taken care to identify two implementations in which the wire intended to lift the bridge has been fixed at the end (in the first case) and in the middle of the bridge (in the second case). He/she asks the class which solution requires least effort, and allows the opinions to flow for a few minutes without confirming any of the points of view. He/she then suggests splitting into small groups to investigate means of proving that a particular solution is better. If he/she finds that all the groups have attached the wire to the end of the bridge, the teacher introduces the activity by asking the pupils why they have chosen that point of attachment rather than some other. Depending on the arguments he/she collects, he/she then involves the pupils in their experimental substantiation. However, as an additional constraint, he/she states that the pupils will not be allowed to construct drawbridges to carry out their investigations. They will have to develop their method based on material explicitly made available to them: various rulers, wooden rods, elastic bands, various masses, string, paper clips, etc. The aim of this constraint is to force the pupils to think about the principle, independently from the object in which it is involved. This method corresponds to real industrial practice. When, for example, it is required to study the efficiency of a new car braking system, a study is performed in a test bed and not on real cars, which would make it too long and too costly

### In small groups

The pupils work out a plan of action. The teacher guides them towards a convincing experiment. The trials undertaken show that the pupils have no particular difficulty in simulating the bridge and in attaching a string in the middle or at the end of the bridge. However, they have difficulty understanding the abstract constraint imposed. They attempt to complete their apparatus by leading the string to a crank, just like in the models they built earlier. It is at this point that the teacher intervenes with appropriate questions: `If you stop the construction at this stage, can't you answer the question being asked?' Other aspects should be noted. The pupils try 'to get a `manual' feel for the effort needed to raise the bridge. But the bridge is too light and the differences are not convincing. Other pupils do not think of making comparisons: they raise the bridge (for example with the wire attached at the end) and then conclude: `Yes, that way is easy...'. For all these and other reasons, it may be useful to provoke an intermediate regrouping.

### Regrouping

This is intended to summarize the difficulties encountered, to compare the solutions thought up and to share ideas:

- What material should be chosen for the experiment? The different suggestions are examined and the discussion should lead to the simplest structure: `a rod lying on a support at one end and supported by a wire at the other end; the wire itself being simply held in the hand.

- How many schemes need to be constructed to answer the question? The objective is for all the groups to understand the need to compare two schemes which differ only in the point of attachment.

- How to overcome the fact that the bridge is too light? Agreement might be reached to make it heavier by placing a box full of nuts (or any other appropriate object) on top of it. It is sufficient to solve these three questions to come up with a convincing experiment which will validate the solution in which the wire is attached as far as possible from the axis. Nevertheless, the teacher may initiate a more scientific questioning concerning the comparison of the forces: `It is not very scientific to measure the effort by hand: can you find a better method? The response generally requires the involvement of the teacher who may suggest using an elastic band supporting a tension sufficient to match the forces in question.  This method is illustrated in Figure 11. It can be applied later to inclined planes if the class becomes involved (see section `To take things further'). After this period of regrouping, all the groups are then able to take up their experiment again.

### Return to small groups

The pupils take up their experiment again, describe it in their experimental notebooks and record their conclusions.

### Collective summary

This is very rapid and its aim is to give an answer to the initial question: `is the bridge easier to lift when the wire is attached far away from the axis?'

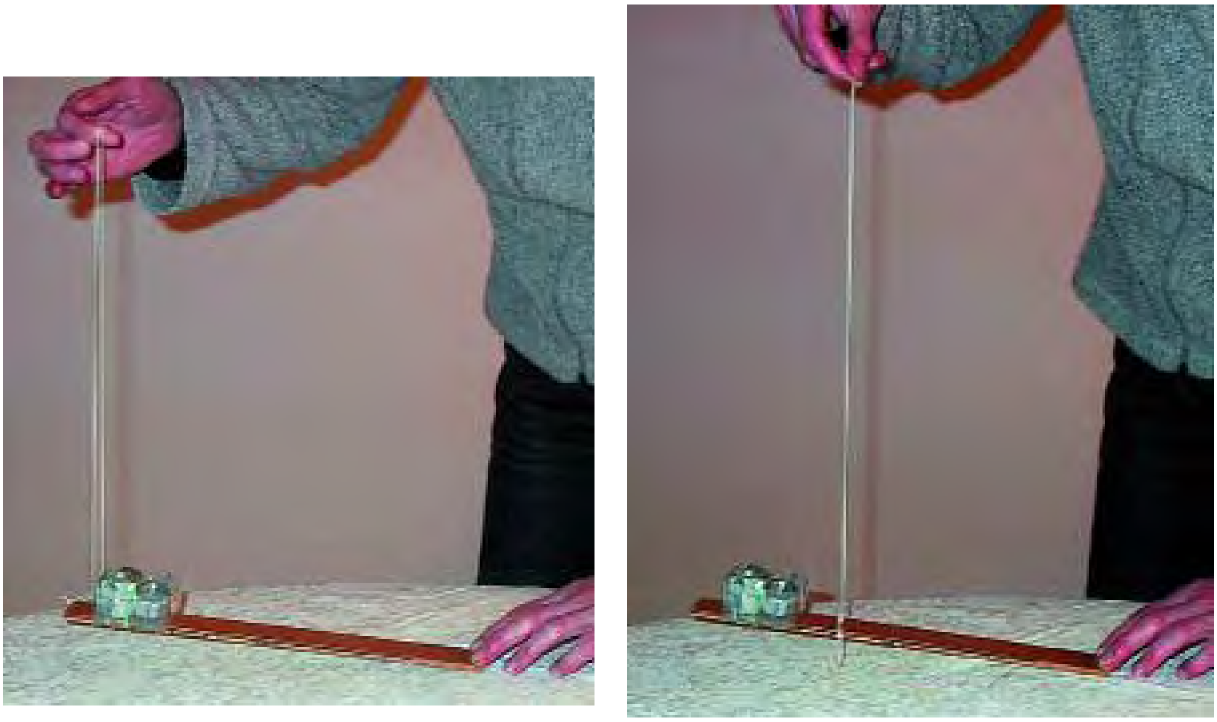


*Figure 11*. Direct perception or measurement with an elastic band: the effect of the position of the point of attachment is perceptible.

## Lesson 7. What is the same, what is not the same?

The pupils relate the activities undertaken in the different lessons to each other and recognize a common principle, under different guises, which they formulate in a more general way.

### Collectively

The teacher returns to two schemes: the ruler supporting a box of nuts and resting on a pivot and the drawbridge bridge made heavier by a box of nuts. He/she reproduces them schematically on the board (see Figure 12).

He issues instructions: in small groups the pupils compare the two drawings and write down in a two column table `what is the same' and `what is not the same'.

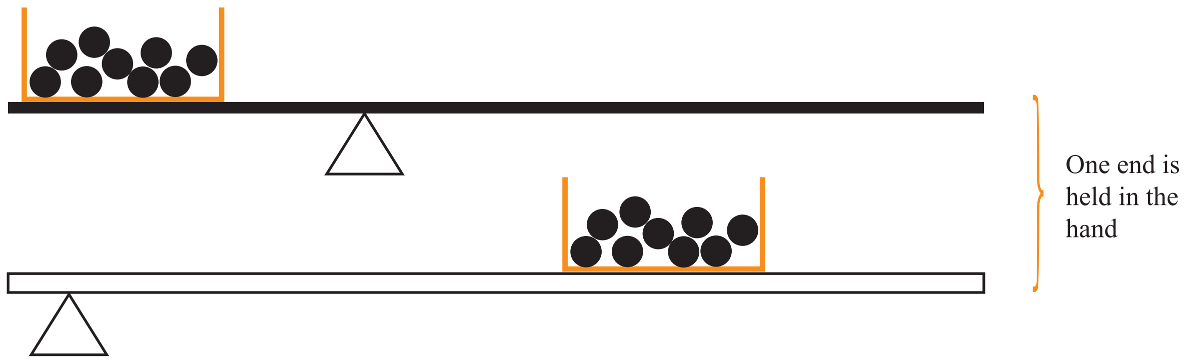



*Figure 12*

**In small groups**

The pupils discuss among themselves and complete their tables.

If they focus solely on the description of the objects and not on the underlying principles, the teacher leads to a second period of reflection through appropriate questioning. `How can you make the effort needed to lift the boxes as small as possible?' `Is it the same in both examples?'.

**Collective summary**

The teacher collects and checks the various suggestions. It is interesting to highlight the similarity of the roles played by the drawbridge axis of rotation and by the pivot. The same applies to the position of the pivot: in some schemes the pivot is located between the points where the forces are applied (the machine of Figure 6, for example), while in other cases it is located at one end (this is the case for the drawbridge).

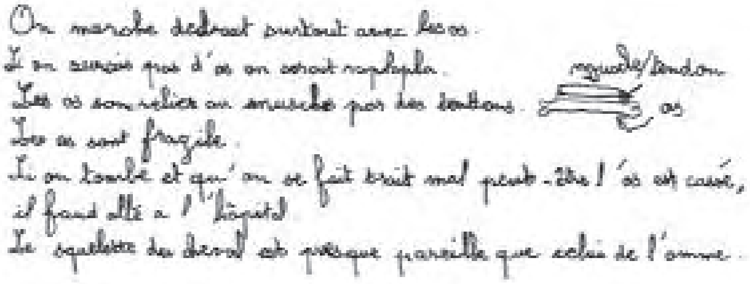
He/she then confirms and reinforces the essential similarity which justifies this period of work. We formulate this below by reproducing the terms of the programme, but other equivalent formulations coming from the pupils are possible: the same force has a greater effect on rotation if it is applied at a greater distance from the axis; a large force has a greater effect than a small force applied at the same distance from the axis.

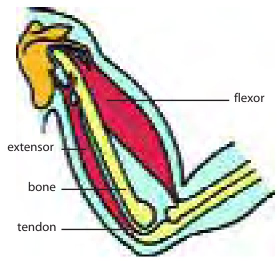
## Lesson 8. Are there levers in living organisms?

The lever principle also arises in the living world, where it is appropriate to demonstrate its presence. The teacher will note however that the pupils have some difficulty isolating the basic lever mechanism within a living organism, and he/she will have to help them establish the necessary schematization.

For example, when asked to think about the points at which tendons are attached to bones, many pupils commit the error illustrated in Figure 13.

Comprehensive work on the role of muscles in movement at the level of joints requires several lessons (we refer readers to an example in our selection of websites). Assuming that this has been undertaken we now put forward two complementary paths involving the lever principle.




*"We walk upright mainly with our bones.*
*If we didn't have bones we would be washed out.*
*Bones are linked to muscles by tendons.*
*Bones are fragile.*
*If we fall and are very badly hurt bones may be broken and we have to go to hospital.*
*Horse's skeleton is almost the same as man's one."*

*"muscle fléchisseur = flexor*
*os (squelette interne) = bone (internal skeleton)*
*muscle extenseur = extensor*
*tendon = tendon"*

*Figure 13.* The attachment of the muscles to the bones: an example of a lever. Left: a common error. Right: the correct picture.

## Insect wing articulation

The pupils read the worksheet (Annex 1). The teacher provides all the useful information for it to be understood by the pupils (possible use of a video document available on the CD ROM). In particular, he/she ensures that the pupils understand the diagram representing a cross section of an insect thorax and the change in scale in the representation of the thickness of the cuticle (evoskeleton). This change is necessary in order that paper fasteners can be attached. He/she also invites the pupils to reread (in their notebook or their textbook) the lesson concerning the human forearm joint and showing the role of muscles.
The pupils then work in proximity to each other so that they can exchange thoughts and ideas among themselves. They carry out the work required on the worksheet individually.
Collectively, the teacher gives a recapitulation, based on the models built by the pupils or on a larger model which he/she has constructed himself/herself (see Figure 14).

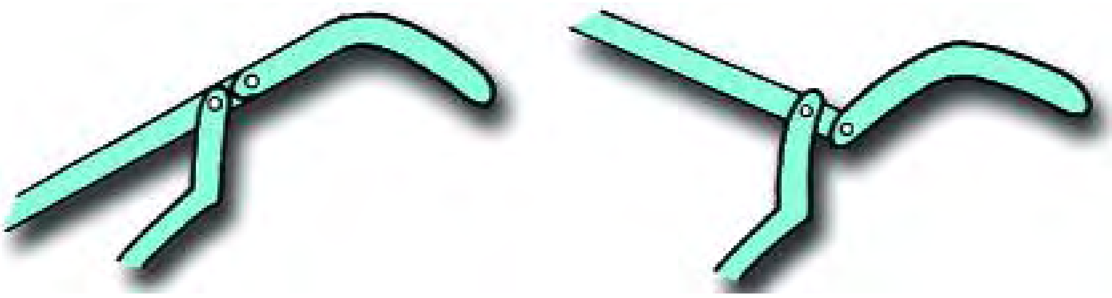


*Figure 14. Models of insect thorax*

The cross section of the thorax, with muscles contracted, which the children expect, is shown in Figure 15, (diagram on the right); it is compared with the diagram in which the muscles are relaxed (Figure 15, diagram on the left).

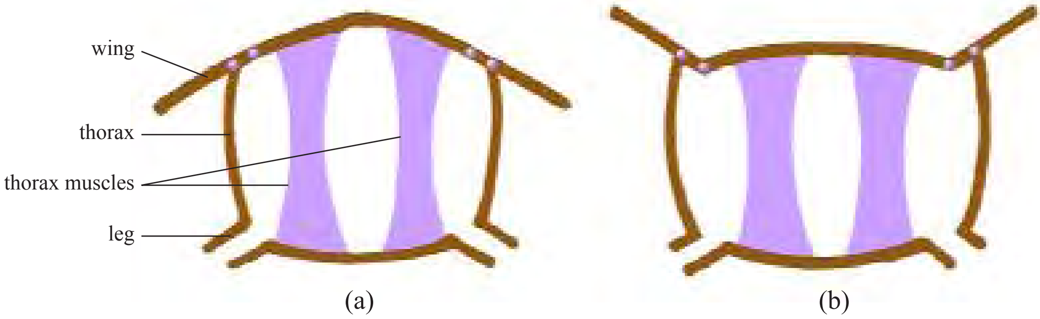



*Figure 15. (a) Thorax, muscle relaxed (b) Thorax, muscles contracted*

### How a crab opens a shellfish (Annex 2)

In a first phase, the teacher hands out shellfish of the whelk species to the pupils. He/she asks them to feel the solidity of the shell with their hands and explains to them how a crab goes about breaking it to access its food (Annex 2 and animation on the CD ROM).
He/she comments on the first illustration which shows how the pincers of the Calappa crab exhibit certain similarities to the levers studied earlier. After positioning the shell correctly, it engages the massive, powerful tooth of its right pincer in the opening of the shellfish, then applies an effort on the side of the shell to break it. Through this opening, it can dig out the interior of the shellfish and access its food, which it grasps using the long, fine finger of its left pincer,

## Conditions for the teaching of the module

### Materials for a group of pupils (see Figure 7)

- A small box of building materials. If the class does not have one, it arranges to borrow one from a neighbouring school or from the pupils themselves.
- A flat ruler or a rod of length 30 to 50 cm and a ruler with a rectangular cross section, whose contact plays the role of pivot.
- Two identical boxes (without lids). These are to be attached to the rulers by rubber bands;
- A supply of identical objects (marbles, bolts, screws, washers, nuts, ...) which will be placed in the boxes.

### Collective materials

- A log (or a rubble stone or a large stone) and a pickaxe handle (or other large stick) with which to lift the teacher's desk (Lesson 2);
- A solid plank of length around 2 m, to be placed on the log (summary of Lesson 4).

### Duration

We suggest an achievable course of eight lessons. Teachers who wish to go into the subject in greater depth can find extensions in the section `To take things further'. Conversely, for those who seek a minimum course length, the first four lessons may suffice. It is also possible to distribute the work over the cycle by tackling the first four lessons in CE2 and the following four in CM1.

### Recommended fact sheets

See sheet no. 24, `Levers and scales' and sheet no. 11, `Movements and displacements'.

## Conclusion

Annex 3 contains evaluation components which can be used to evaluate the knowledge and skills acquired. The pupils have to indicate whether the lever principle is present in the various illustrations (of varying difficulty) presented to them.

## Taking things further

### Scales, the concept of equilibrium

Satrting from the classical situation of the child who wants to play on a seesaw with an adult (taller, heavier), the pupils might be asked to apply their knowledge of levers. (Where should the pivot for the seesaw be placed? With a fixed pivot, where should the adult be placed and where should the child be placed?). After this work one might suggest the construction of a steelyard consisting of a rod suspended by a ring at a point close to one end. The aim is to achieve a balance between a load hooked on at the end and a counterweight (ball of plasticene, washers, ...) which will be slid along the rod using a paper clip.

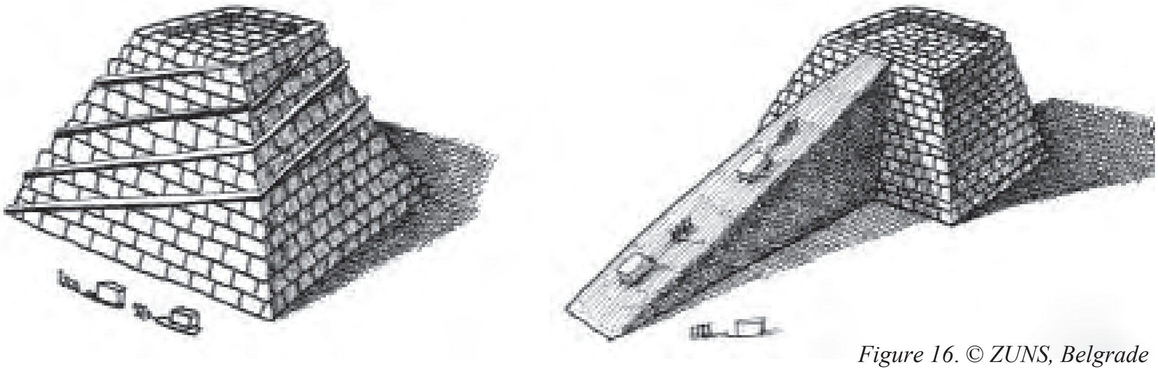


*Figure 16. © ZUNS, Belgrade*

### The building of the pyramids: levers or inclined planes

If the activity of Lesson 6 was completed, the pupils will have a means of comparing forces (Figure 11). This is of course rudimentary, but sufficient for the purposes in hand. The elements of the debate can be presented quickly using a short text (to be explained with the pupils) and a few pictures.

`New hypotheses cast doubt upon the use of ramps to build the pyramids of Egypt'.

You are the architect of the Pharaoh Cheops and he wants his tomb to be the biggest pyramid ever built. His wishes are divine orders and your head is on the block, so you bring together your study advisers to think about the problem. How can you assemble thousands of 2.5 tonne blocks of limestone and 90 2.5 tonne blocks of granite?

Egyptologists are still bogged down in conjectures about the methods of Egyptian architects. There are two opposing schools. The most widespread view is that an inclined ramp, on which people dragged blocks of stone, was progressively constructed, heightened and extended. According to the second view, wooden machines using the lever principle hoisted the stone blocks from one horizontal level to the next[4]. The adherents of the `machinist' thesis (levers) include the architect Pierre Crozat who recently proposed a system consistent with the writings of the Greek historian Herodotus (484 BC; 420 BC). (...)'.

*©Pour la science, no. 265, November 1999.*

The pupils then have to work in small groups to examine the alternative principle to levers and demonstrate experimentally that the effort needed to lift a load is less if one takes the precaution to limit friction (polished or soaped surfaces), when the load is dragged along an inclined plane than when it is lifted vertically.

## Tentative selection of sites

### History

- A page of history on mechanics in Alexandria:
www.cnam.fr/museum/revue/ref/r20a04.html
- The drawbridge of the castle of Coudray-Salbart:
http://visite.salbart.org/index.php3?url=t-portal.php3
- The drawbridge at the gates to the city of Carcassone
http://ecole.wanadoo.fr/lagravette.carcassonne/patrimoine/pont.htm
- The storming of the Bastille began with the destruction of the drawbridge
www.diagnopsy.com/Revolution/Rev_008.htm
- History of movable iron bridges (including a drawbridge) in Tournai on the Escaut
www.met.be/metpub/src/actu12/p09.html

### Engineering objects

- A photo of the drawbridge of the port of Marseilles
http://sarkis.com/photo/MARSEILLE/PONT.html
- The lever system in different types of piano keys (diagrams)
www.pianomajeur.net/hist05.htm

[4]These machines are similar to those presented to the pupils in Lesson 2 (Figure 6).

- Very rich site addressed to fans of mountain biking; lever system visible on the photograph:
http://perso.libertysurf.fr/cyclenet/transmission.htm#manivelles
- A pulley system for a ski lift (photograph included)
www.gimar-montaz-mautino.fr/produit/teleski.htm
- A boat pulley (photograph included)
www.vlevelly.com/Bateaux/poulie.html
- Fixed pulley, movable pulley and hoist
www.total.net/~lego/poulie.htm

### Various

- Model of a fortified castle with drawbridge to be built by a child at home:
www.tiboo.com/tibooparc/bricolages/chateau-fort.htm
- An experiment with laboratory rats, which know how to manipulate a lever using their powers of mental concentration only
www.sciencepresse.qc.ca/archives/cap2806994.html
- A very educational pupil page on the lever principle (other: pulleys, winch,...)
http://esjn.csriveraine.qc.ca/Travaux/etudiants/physique/peleve99/colldaveweb/leviers.html
- Construction of a winch to erect a wind turbine:
http://eoliennes.free.fr/treuil_c.html
- Site devoted to the tendinitis of Achilles' tendon, which explains (text + diagram) that this tendon implements a lever and pulley system
www.domyos.com/running/fr/html/CourseSante/ru10d.asp

### Educational activities

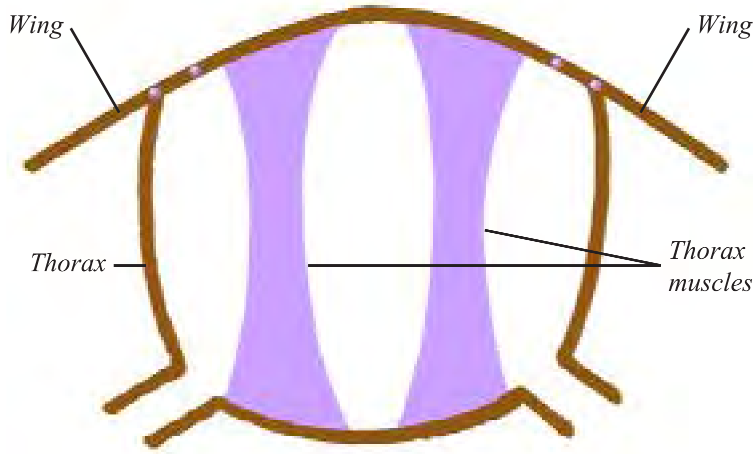
Here is a selection of activities proposed on the *La main à la pâte* website:
- Six lessons on bodily movementswww.inrp.fr/lamap/activites/locomotion/sequence/mouvement/sommaire.htm
- Insight programme for the study of sciences at elementary school, `lifting heavy things'
www.inrp.fr/lamap/activites/insights/chose_lourde/accueil.html
- The equilibrium of a crane
www.inrp.fr/lamap/activites/leviers_balances/module/equilibre_grue/accueil.html
- Mobiles in equilibrium
www.inrp.fr/lamap/activites/leviers_balances/sequence/mobile.htm
www.perigord.tm.fr/~eclsciences/PAGES/OBJetTEC/EQUIMOBI/SoEqMobi.htm
- From the drawbridge to levers
www.inrp.fr/lamap/activites/objets_techniques/idees/temoignage/pont_levis.htm
- A complete site on the topic of levers and equilibrium produced by a school
www.edres74.cur-archamps.fr/sprof/gdes74/seance/levier.htm
- Sheets for teaching physics and technology in the 3 cycles.
www.ac-grenoble.fr/savoie/Disciplines/Sciences/Esp_ress/phys-tec.htm
For example
www.ac-grenoble.fr/savoie/Disciplines/Sciences/Esp_ress/Fiches/Plans-i.htm
www.ac-grenoble.fr/savoie/Disciplines/Sciences/Esp_ress/Fiches/Leviers.htm
www.ac-grenoble.fr/savoie/Disciplines/Sciences/Esp_ress/Fiches/Plans-i2.htm
www.ac-grenoble.fr/savoie/Disciplines/Sciences/Esp_ress/Fiches/Poulies.htm

## Sources

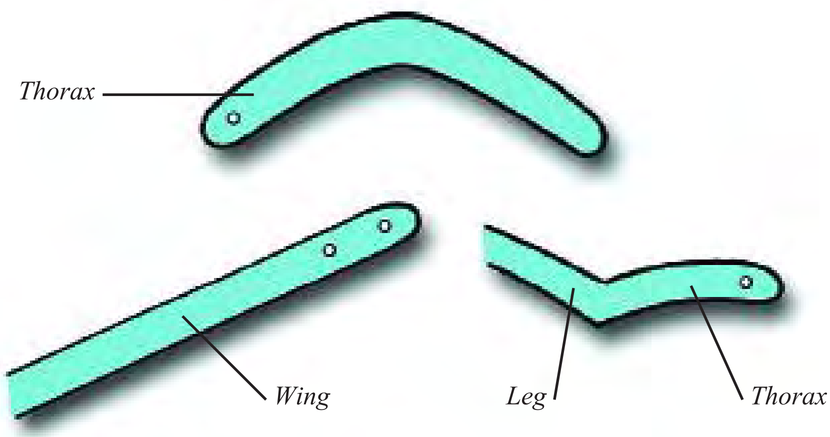
Work trialled in the CE2-CM1-CM2 class of the Le Chaumet school in Évires (74), in the CE2 class of the Fins school in Annecy and in various classes of the Jean Vilar, Martin-Luther King and Courcelles elementary schools in Vaulx-enVelin.

# Insect flight[5]

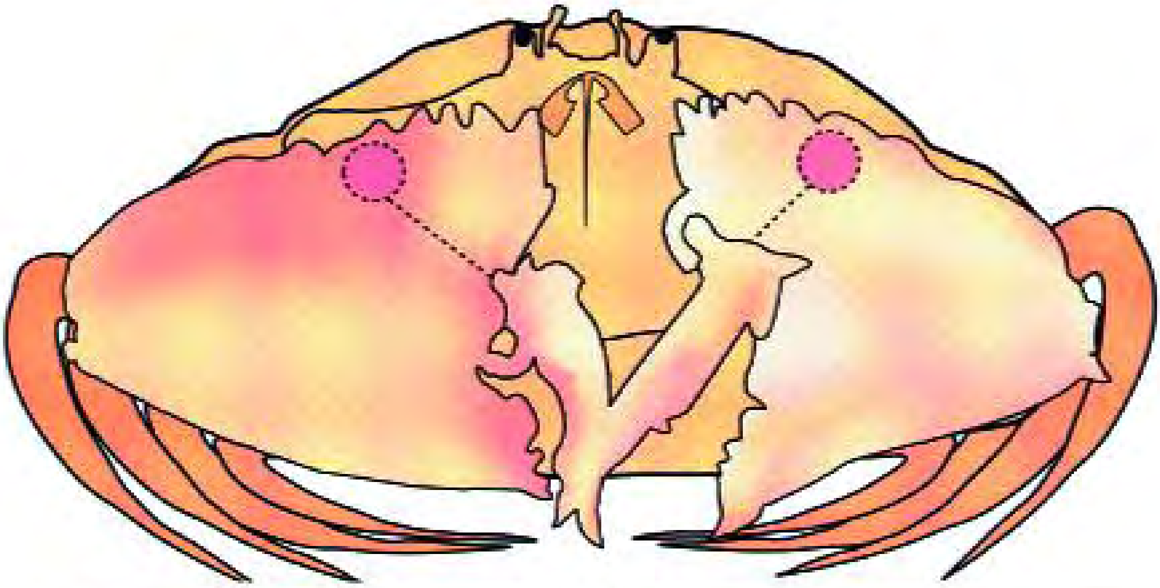
The diagram below represents a cross section of an insect thorax when the muscles are relaxed. For simplicity, certain muscles are not shown.

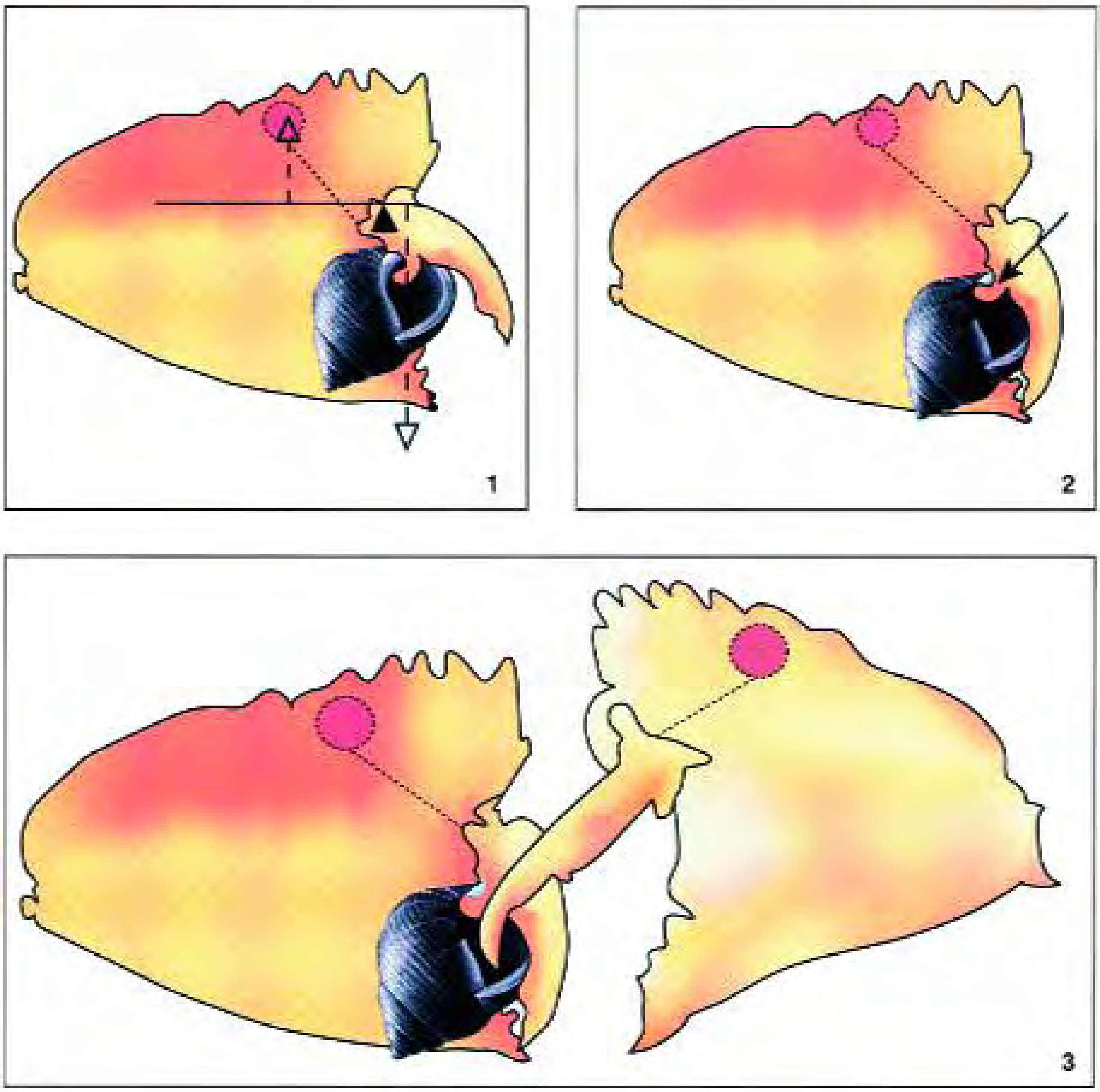



Copy the shapes below on to card and cut them out. They represent the left-hand side of the above cross section. Construct the wing joints using paper fasteners and operate them.




In your experimental notebook, sketch a cross section of the thorax with the muscles contracted.

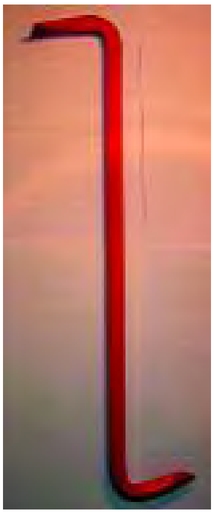





The annotation (arrows) on Figure 1 indicates that the small force applied by the muscles of the crab's pincer leads to the application of a large force on the shellfish, taking into account the distances from the pivot.

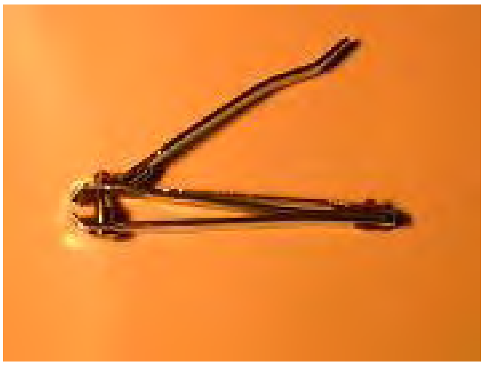
Here, we propose components which will enable teachers to evaluate how well their pupils have acquired the three skills relating to levers: identification of schemes using the lever principle; understanding of the role of the distances between the pivot and the point at which the forces are applied; identification of the lever principle in more complex schemes not studied in this module. They can be used at any time during the module. Their role is simply formative, that is to say intended to show the pupils what they have learnt.

1. Observe these objects and indicate those which work on the lever principle.



Picture 1. A nail wrench

Picture 2. A nutcracker



Picture 3. A nail clipper

Picture 4. Pencil case and it's zip fasterner

Picture 5. © SEAMEO RECSAM, Penang, 2007

Picture 6. An office hole punch

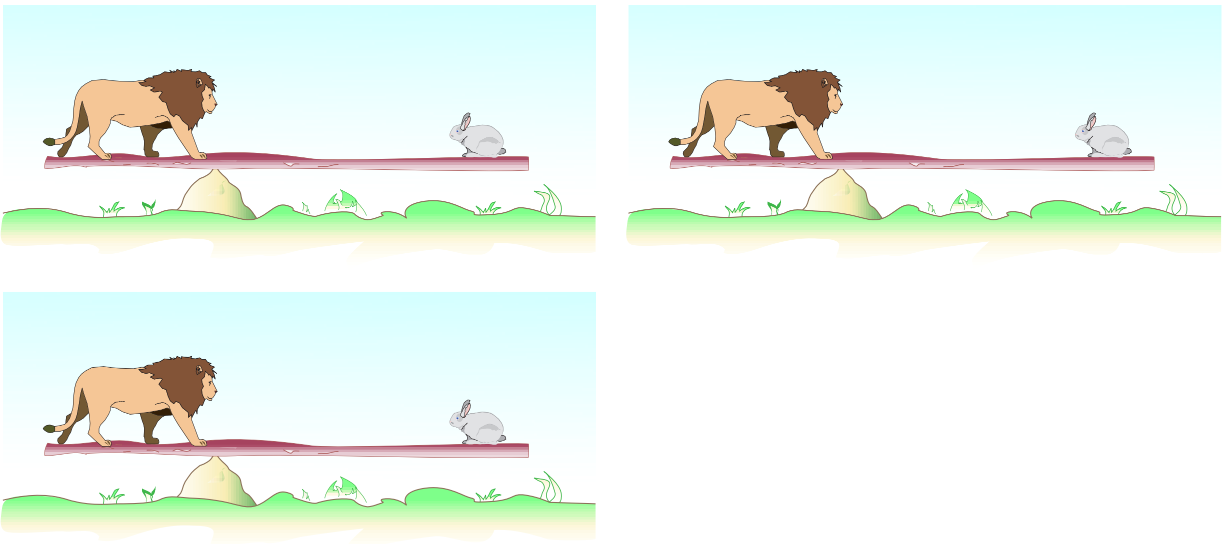
Picture 7. A drill

Notes for the teacher
Schemes using levers (1, 2, 3, 5, 6)
Schemes which do not use levers, at least in any evident way (4, 7)
It is advisable that the schemes chosen should be very varied. Some are very similar to those which have been studied (Picture 5), others less so. The pupils may think that a lever necessarily consists of a rectilinear rod. The nail wrench and the nail clippers are levers with a bend in them. They may think that a lever is solely intended to lift large loads, which leads the teacher to put forward pictures such as the hole punch or the nail clippers. They may also believe that a lever is always a tool (in the sense of do-it-yourself), whence the presentation of the office hole punch, the nutcrackers (which are levers) or the drill (which is a tool in which there are no levers[6]).

2 Look at the picture below. Can you see schemes which work on the lever principle? Which ones?

Extracted from *Mesin-mesin ringkas di tapak pembinaan, Transperensi 6-7, Menyiasat Dunia Teknologi (Simple machines in a construction site, Transparency 6-7 in Investigating the world of Technology)* © Ferringhi Distributor, Penang, 1997, reproduced with the permisssion of Ferringhi Distributor, Penang

3 Look at the lion and the rabbit
Is it possible for their seesaw to be balanced in one or more of these diagrams? Circle the case(s) in which it is possible.



[6]In fact, a  precise study of the drill would reveal, for example, the on-off trigger. But at primary school level, and taking into account the work undertaken, it seems reasonable not to enter into the detail.

4. Look at the diagram below.

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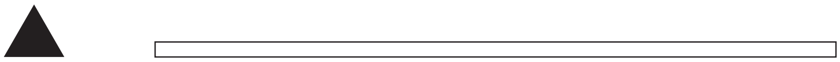
Draw the plank and the pivot as they have been arranged by the acrobats. Why have they been placed like that?



Notes for the teacher

Exercises 3 and 4 aim to determine whether the pupils have understood the influence of the position of the pivot (far from the load to be propelled in the case of the acrobatics illustration) and of the point at which the forces are applied.

cycle 3

# How do we know where the wind comes from ?

*Figure 16.* © ZUNS, Belgrade

This module provides the opportunity to illustrate the linkage between science (building up of knowledge: here, the fact that air is matter, the effects of forces) and technology (construction of an object whose function and use are defined).
- Moving air can produce a force and create movement.
- This effect can be used to operate certain objects.
- The functions of these objects may include the production of energy (windmill, wind turbine), indication of a direction (windsock, wind vane). The windsock also provides information about the wind speed.

Here, as much for simplicity as out of educational interest (existence of an axis of rotation, connection with the identification of the cardinal points), we shall consider the building of an object (wind vane) with the second function. .

Making reference to the optional module of the programme on energy, one might imagine an analogous module leading to the construction of a wind turbine or a sand yacht, etc.

## Position in the programmes

- In cycle 2**:** in the context of the study of matter, the pupils have learnt about the existence of air. They have also touched upon the gaseous state through the material nature of the air. In the context of the study of geographical space, they have learnt how to represent the near environment, get their bearings and orientate themselves. They are able to give an oral description of and locate the various elements of an organized space.
- In cycle 3: this module on the wind falls within several parts of the experimental sciences and technology programme and also within the mathematics programme:

<table>
<tr><th rowspan="2">Extracts from the programme</th><th colspan="2">Extracts from the application document</th></tr>
<tr><th>Specific skills</th><th>Remarks</th></tr>
<tr><td rowspan="2">World constructed by man<br>The pupil is initiated, via a practical implementation, into the search for technical solutions, and into the choice and well thought out use of objects and materials.<br>- Levers and scales; equilibria;<br>- Mechanical objects; transmission of movements.<br><br>Matter<br>- Air, the fact that it has a mass<br>- Horizontal and vertical planes: interest of certain technical devices.<br><br>Energy<br>- Simple examples of usable energy sources (the wind is a source of energy)<br><br>The heavens and the Earth<br>- The cardinal points and the compass<br><br>Space and geometry<br>(mathematics programme)<br>- Geometric relationships and properties: alignment, perpendicularity, axial symmetry</td><td colspan="2">“In pursuit of the activities covered in cycle 2, the pupil is initiated, via a practical implementation, into the search for technical solutions, and into the reasoned choice and well thought out use of objects and materials.”</td></tr>
<tr><td>Ability to anticipate or qualititatively interpret a number of equilibrium situations, in particular when the forces which are applied are not at an equal distance from the axis.<br>Ability to use the following two properties to do that:<br>- the same force has a greater effect on rotation if it is applied at a greater distance from the axis;<br>- a large force has a greater effect than a small force applied at the same distance from the axis.</td><td>The pupils' (purely qualitative) thought processes are exercised through effective, concrete implementations.<br>Possible examples:<br>the construction of a crane and the equilibrium of the jib, the construction and equilibrium of a mobile, the construction or use of pincers, levers, etc.<br>Study of their effectiveness...</td></tr>
</table>

- At Collège: the concept of force will be introduced
- At the Lycée: the movement of a solid in rotation about an axis, the work of a force and energy will be studied.

### Knowledge and know-how which it is desirable for pupils to acquire or be acquiring at the end of the module

Wind is a displacement of air with respect to a reference point, its effects are perceptible. Air applies forces on an object with respect to which it is moving. These forces affect the shape (and/or) the position of the object.
In equilibrium position, a wind vane indicates the direction of the local wind if the surface areas[1] on either side of the axis of rotation are very different; the upwind part is that with the smaller surface area. It therefore indicates where the wind comes from.

[1]See the next section, `One possible way in which the module might be taught'.

## One possible way in which the module might be taught

The lessons below are not of equal importance and do not need to be taught entirely at this point and in this order; they need not be taught in a uniform linear sequence in time.
There are many possible scenarii, nevertheless, Lessons 2, 3, 4 and 5 undeniably constitute a core, albeit a divisible one. It is up to the teachers to add to this core whichever lesson appears most opportune to them, depending on their teaching plans. In particular, Lesson 7 can be integrated into Lesson 4 in a natural way.

Some examples of the order in which the lessons can be taught:
- Lessons 2, 3, 4 and 5
- Lessons 6, 2, 3, 4 and 5
- Lessons 2, 3, 7, 4 and 5
- Lessons 2, 3, 4, 7, 5, 8....

N.B. Lesson 1 would be more appropriate to cycle 2, however if it is given immediately before the following lessons the pupils will move more quickly in Lesson 2 towards the question of orientation and possible reference points.

| Lessons | Starting question | Activities undertaken with the pupils | Scientific approach | Knowledge, facts and know-how brought into play |
|---|---|---|---|---|
| Lesson 1 | What are the effects of the wind? | Based on their sensory experience and their observations, the pupils identify phenomena which provide evidence of the wind. They attempt to describe these. | Observations | Ability to distinguish natural elements from man-made objects |
| Lesson 2 | Which objects indicate the direction of the wind? | Short lesson, leading to the emergence of the fact that the wind exerts forces upon the objects it meets and can lead to their movement | Proposals for experiments | Reasoning ability<br>Presentational ability |
| Lesson 3 | What are the characteristics of these objects? | The pupils test some or all of the proposals made in the previous lesson. | First experimentation and working out of the expected characteristics of the object | Ability to select pertinent information.<br>Comprehension that wind is air which is moving with respect to a reference point |
| Lesson 4 | How to make a weather vane | The pupils are confronted with situations which bring to the fore the masses and surface areas on either side of the axis of rotation. | First implementations | Comprehension that the wind exerts forces on the object<br>Observation that the wind vane indicates the local wind direction if the surface areas on either side of the axis are very different |
| Lesson 5 | Construction of a weather vane | The pupils build a wind vane corresponding to fixed criteria and test it in the light of the preceding experiments. | Construction and validation | Ability to construct a technical device corresponding to precise constraints |

| Lessons | Starting question | Activities undertaken with the pupils | Scientific approach | Knowledge, facts and know-how brought into play |
|---|---|---|---|---|
| Lesson 6 | Why do we want to know where the wind is coming from? | Through the use of documents, the pupils think about the historical and social role of man-made objects which correspond to the need to know the wind direction. They make comparisons with the present-day situation. | Documentary research | Knowledge of how to find pertinent information in a document |
| Lesson 7 | How to identify the wind direction? | In seeking to describe the wind direction (at school, on an outing, on a plan or a map) the pupils are led to use the concepts of `local referencing' and `geographical referencing' (cardinal points). | Observations | Ability to distinguish between `local referencing' and `geographical referencing'.<br>Ability to use a compass |
| Lesson 8 | What are the dominant winds? | The pupils make regular recordings of the wind direction given by the wind vane and observe the variability of the local winds. | Observations and implementations | Collection of data in pertinent forms.<br>Representation of data using mathematical tools and interpretation of these data. |

# Lesson 1. What are the effects of the wind?

In this lesson, the pupils apply their observations and their sensory experience to identify phenomena which provide evidence of the wind; they then try to describe these.

### Objectives

- Initial introduction to the effects of the wind on natural elements or on man-made objects.
- Explicit distinction between what is man-made and what is not.
- Enrichment of the vocabulary related to the phenomena observed.
- Enrichment of the language related to the specific details of the situations (observations, descriptions, interpretations, trials,...).

### Initial situation, questioning

So that the pupils do not become embroiled in excessively formal questions or conventional answers, a scenario of the following type may be put forward:
“F. says that it is windy today; look outside and find evidence that will enable him to justify that statement.”

### Examples of pupil responses

Leaves, branches of trees, hair, a wet finger, dust, soil, sand, smoke, `steam' from chimneys, a scrap of cloth, washing drying on a washing line, clouds moving, a scrap of paper, a windsock, a wind vane, a kite...

### Analysis of the responses and elaboration of the problem

`What are the differences between all these suggestions, how can they be classified?' It does not seem realistic to expect pupils in cycle 2 to think up the desired classification themselves (man-made, natural). The teacher can legitimately lead in this distinction by taking charge of oral exchanges in the class group and coming up with three categories:
- the effects of the wind on the body, perceived using the five senses;
- the effects of the wind on natural elements;
- the effects of the wind on man-made objects.

### Design of investigations by the pupils
The pupils will be asked to develop and experiment with a device in the third category. This will lead to a new distinction between:
- man-made objects designed to obtain information about the wind (speed, direction). If the compass and the wind rose have been cited, they will be provisionally classified in this category to be put to the test, the obstacle will be surmounted later.
- Objects affected by the wind but which were not built to obtain information about the wind (tiles which are blown off, an umbrella which is turned inside out,...).

### Records, work on the language
Pupils' written work may be requested in order to:
- formalize the first observations in the framework provided by the three categories (description, justification of the classification into a particular category);
- suggest simple constructions to be tested.

The written work is needed to teach classification and presentational skills. Example of enrichment of the vocabulary: to swirl, to twirl around, to disperse... Tiles are flung about, paper is not; leaves twirl around, tiles do not....

### Examples of schemes constructed
Water in an almost full glass (there are wavelets on the water surface when there is a wind), rag attached to a weighted-down bottle, paper attached to a string...
It is desirable to test these schemes outdoors. In turn, they will give rise to written descriptions in the experimental notebooks.

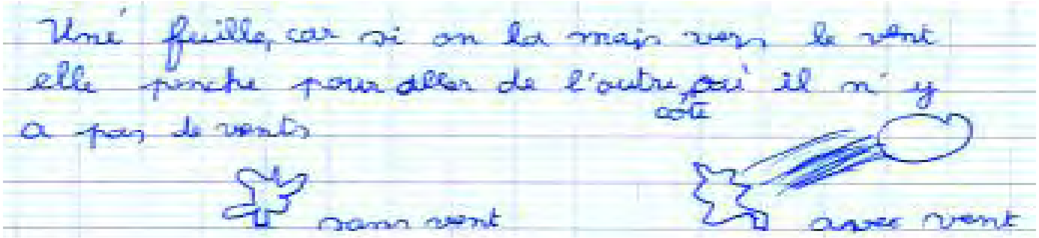
## Lesson 2. Which objects indicate the direction of the wind?
The pupils think up devices which can be used to determine the wind direction. This short lesson can be split over two consecutive periods.

### Objective
The pupils' designs will be described explicitly and subjected to a first analysis in order to specify the ultimate aim of the activity

### Instructions
Each pupil is to answer the following two questions: `Do you know any objects which can be used to determine where the wind is coming from? How are they used?'
The pupils describe their suggestions in their notebooks, using drawings and text. The teacher will ensure that the instructions have been fully understood. It has been observed that, depending on their age and prior experience, the pupils may have difficulty in distinguishing between the question about the origin (the cause) of the wind and that of its direction. The question `Why is it windy?' would be legitimate, but that problem is too complex for the school, and will not be dealt with here.

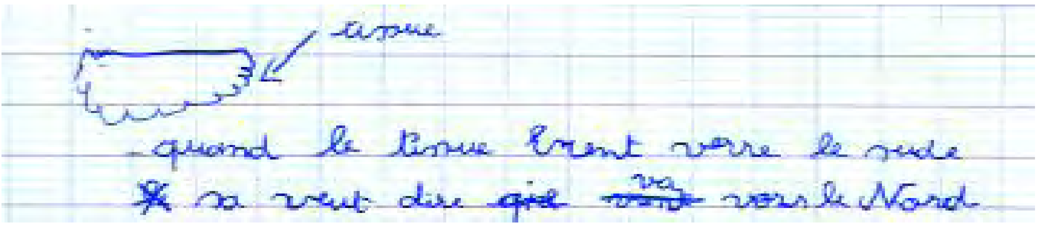
### Examples of schemes suggested by the pupils
- "I shall take a balloon on a string and look at the direction in which the balloon moves."
- "I shall take a loose leaf notebook and then turn my notebook so that the wind makes the pages turn."
- "I shall attach a piece of string, a cloth, to a stick."
- "I shall attach a pierced bottle to a stick."
- "I shall take a flag."
- "I shall take a wind vane."
- "With a satellite."
- "With a compass[2]."

[2]The last propositions are irrelevant. They will see it later.




*"A leaf, because if you have your hand towards the wind it tips up to go to the other side where there is no wind." " Sans vent" =" no wind"; "avec vent" = "with wind"*


*"How does it work: a compass is used to show where the wind is"*
*N = N; E = E; S = S; O = W*




*"tissue = cloth"; "When the cloth comes towards the South, this means that the wind is going to the North"*

*Figure 2*

**Management of the pupils' suggestions**

This can be done in two ways to end up with productive questions (see the paragraph `Benchmarks for teaching a module' in the Introduction).

- Immediate handling:

The teacher proposes that the pupils' suggestions should be classified into the following categories, established *a priori.* Each group (ranging from four to six pupils) will work out a well reasoned classification of its members' suggestions and will write down its proposals on a poster. By comparing the posters the teacher will be able to lead a discussion to establish the obstacles, and restrict the selections to those which are relevant in the context of the module.

- Delayed handling:

All the suggestions are recorded by the teacher. There are two possible teaching approaches:

- The pupils, for example in pairs, agree to assign all the suggestions recorded by the teacher to given categories (established *a priori* in this case also). Comparisons in groups of four, and then between groups, will permit the development of a well reasoned classification which will be presented to the class.
- In small groups, the pupils work out categories themselves, with reference to the work carried

out during Lesson 1. They propose a classification. The interactions and the discussion will then revolve around the criteria for categorising and on the distribution of the responses according to these criteria.

### Example of possible categories

Category 1: schemes which answer the problem but which cannot be constructed in class. There are satellites which observe the atmosphere from space and can be used to determine the wind direction (for example, over the oceans), but we are not going to build a satellite in class!
Category 2: schemes which make a direct call on one of our five senses: the noise of the wind in our ears, a wet finger.
Category 3: schemes associated with the observation of phenomena in the environment: the direction of smoke, the direction in which trees are leaning, leaves which fly away...
Category 4: objects: weather vane, windsock, woollen thread, compass, wind rose. Here, one can distinguish between
- objects which are deformed under the action of the wind (string, liquid);
- objects which move around a fixed position (hanging objects)

Constructions suggested in this category will be built and tested in what follows.

### Suggestions

The reasons why categories 1, 2 and 3 are kept out of things will be explained:
- category 1: lack of realism
- category 2: too subjective, associated with an individual;
- category 3: not reproducible, not universal and imprecise.

A strategy is deduced: to build a technical object which is affected by the forces exerted upon it by the wind and indicates their direction in a stable manner.

### Records

The collective records, aids and summaries of exchanges have been described above. However, each pupil may reformulate whatever is personally relevant to him/her more precisely in his/her experimental notebook.

In these possible formulations, emphasis should be given to anything which says that in order to determine the wind direction one needs an object which is either deformed or becomes oriented in a particular direction under the action of the wind.

## Lesson 3. What are the characteristics of these objects?

This lesson involves initial experimentation and determination of the expected object characteristics. The pupils testsome or all of the proposals put forward in the previous lesson and begin to define the functional characteristics of the object. This lesson is long and may therefore need to be taught in two separate sessions.

### Objective

Based on tests performed on the objects proposed and accepted, the pupils will discover certain conditions which are needed for the object to answer the two questions set at the beginning of the second lesson, and will hence determine the characteristics of the object to be built (at this stage, it is still a choice between a wind vane and a windsock).
This lesson will explicitly pose and deal with the question: `How can wind be produced?'

### Instructions

The scheme selected will enable each pupil to test his/her own ideas, which have already been transformed to some extent during Lesson 2, experimentally.
To ensure that their individual work is really productive, the pupils will be split up, preferably into pairs. However, the teacher will assess the best level of regrouping, depending on the class's own dynamics.
- Invent and test an object which indicates where the wind is coming from; this therefore needs wind. How can wind be produced?

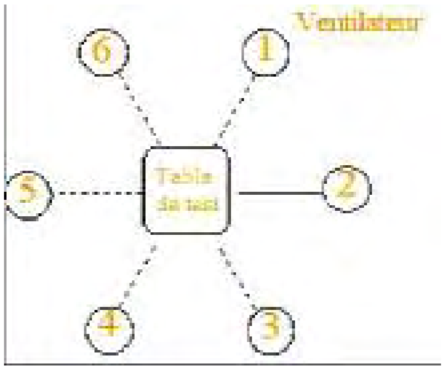
The objects to be tested will be chosen from among those suggested by the pupils during the previous lesson.
If they have not already been eliminated by the pupils, the irrelevant (compass, wind rose) or imprecise (woollen thread) solutions will be ruled out during this lesson. After the initial attempts to build something, the teacher will lead the pupils towards the construction of a wind vane. The windsock, with which the pupils are often quite familiar, remains a relevant solution.

The question of pinpointing the wind direction will be raised, either based on suggestions by the pupils or with the help of the test apparatus described below.

### Investigations undertaken by the pupils

The test system for the devices can be set up as follows (see Figure 3). For the fan to be used in complete safety, it must be fitted with a protective grill preventing all contact with the fan blades. If the question of pinpointing the direction does not emerge immediately, it will be postponed (see Lesson 7). The experiment will be more conclusive with a fan with a sufficiently large diameter (10 to 20 cm).

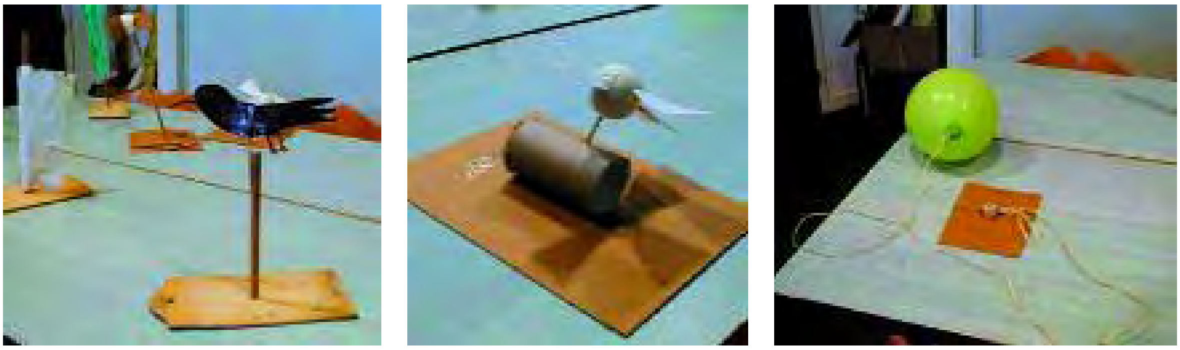
*"Ventilateur = Fan"*
*"Table de test = Test bench"*




A trolley with a fan on it can be moved around a fixed table (test bench). Care must be taken to ensure that the air flow passes at a sufficient height above the table (20 cm or more).
The trolley can be positioned in various regularly spaced positions around the test bench, as illustrated by the six numbered locations on the diagram.
The object to be tested is placed in the middle of the test bench.
The devices built by the pupils should make it possible to determine where the fan is positioned; they will provide different information when the fan occupies each position.

*Figure 3.* Test system for the devices built by the class.

To record the tests undertaken using a particular device, one might use plans based on the scheme of Figure 3, data encoded on to given media, or other suggestions made by the pupils.
However, it is not always advisable to impose intermediate reference points (such as, for example, the positions of the test apparatus) for the pupils who are likely to resort to the notions of North, South, East, West, North-East, etc. intuitively. In the same way, if these reference points have been explicitly defined in the classroom (for example, in geography), it would be appropriate to use them.
The observations of the behaviour of the objects built and the interpretations placed on these by their builders will be compared and contrasted in comparisons organized by the teacher. These discussions will make it possible to determine the characteristics that the object must have for it to perform the required function.



Bird wine vane — Windsock on a pedestal — Balloon on a string

*Figure 4.* Examples of implementations.

### Records

In their experimental notebooks, the pupils note down their construction plans, their expectations, tests and observations. They also record their reasons for choosing or abandoning the device tested.

The need for reference points will arise from the need to communicate or make a record (for example, if this work is undertaken in an unscheduled class). Questions such as `where does the wind go?', `how can one tell if the wind always comes from the same direction?', might also be introduced.

### Examples of observations which may give rise to a discussion leading to the development of criteria on device construction

- The device indicates a variable direction even when the wind is regular, it has no equilibrium position (case of a length of wool, for example).
- The device does not withstand strong wind or is deformed by strong wind (remedy: construction of pedestals, shrouding).
- The device does not indicate anything if the wind is not strong (threshold problem).
- The device is not rain resistant.

### Examples of finalized written material

- Wind is a flow of air from one place (upwind) to another place (downwind) and thus has a direction in a given reference system.
- An object which turns under the action of the wind may indicate where the wind is coming from.
- For it to be possible to name this direction, the object must have a pointer and there must be a local or geographical (cardinal points) reference point.

### Examples of characteristics found by a class

- Asymmetry of objects to enable them to indicate the direction (distinguish between upwind and downwind, where it comes from..., where it goes to...);
- For a device with an axis of rotation; the axis must be vertical and friction must be minimized;
- Sensitivity to the wind (materials, shapes);
- Stabilization of the device in a position indicating the wind direction.

### Some tips

The question `how can wind be produced?' should be answered quite easily in experimentation by the pupils. The wind produced can be readily associated with the use of a fan. Wind is moving air.

It is vital to make this notion clear by introducing the idea of movement with respect to a reference point; for this, the teacher may suggest comparative observation between:
- the fan setting the air in motion;
- the displacement of windmill arms (or a windsock) in the air, leading to rotation of the arms (or inflation of the windsock)

This should permit the conclusion that wind is a displacement of air with respect to a reference point (concept of relative movement).

# Lesson 4. How to make a weather vane?

In this lesson, the pupils will be confronted with situations revealing, in particular, the role of the parts on either side of the weather-vane axis.

## Objective

To make apparent, by tests and supplementary experiments if necessary, one of the essential constraints on the wind vane: the distribution of the masses and surface areas on either side of the axis.
To answer the question: `how does the wind act?'

## Comments for teachers

The construction, under good technical conditions (no torsion exerted on the axis, minimization of friction) requires the equilibration of the masses on each side of the axis. If these conditions are not met the device life time is reduced. Moreover, friction restricts the device precision.
This equilibration is obtained if the centre of gravity of the system lies on the axis. It can be achieved as follows: in the absence of wind, the axis is placed horizontally, when the wind vane is turned to any position it must stay there (physicists speak of immaterial equilibrium)
From a physical point of view, this is only in the case when the surface areas on either side of the axis are very different, so that the equilibrium position of the wind vane is parallel to the wind, with the smaller surface areas pointing upwind and indicating the direction from which the wind is coming. This condition is important.

Surprisingly, a device consisting of two planar plaques symmetric with respect to the axis can even be observed to adopt an equilibrium position perpendicular to the wind, in an exception to a simple empirical rule in which the devices studied take up a direction which minimizes the extent to which they are caught in the wind.

There is no question of presenting the above explanations to the pupils. They are intended to help the teacher to interpret the results of the pupils' experimentation and to guide the latter in their empirical discoveries.

## Suggestion for experimentation which may be proposed by the teacher

Slightly asymmetric wind vanes are given to the pupils with the following instructions: `test this device and suggest improvements so that it gives a better indication of the wind direction'.

It is a matter of getting the pupils to observe the imperfection of this device; it will be easy to carry out an experiment showing that the wind vane indicates a direction which is clearly different from that of the wind. By interpretation and more or less empirical analysis of the results obtained, the pupils will be led to make the surface areas of the two plaques on either side of the axis of rotation highly asymmetric. In the same way, care should be taken to observe to the pupils that if the fan is regulated identically, different surface areas caught by the wind lead to different movements.

This observation can be used to broach the question `how does the wind act?', but this can also be introduced based on remarks by the pupils of the form: `the wind makes the wind vane fall' or `the wind pushes the wind vane', or even by questions asked by the teacher during or after the experimentation. It may be interesting to prepare for this stage, during experimental lessons, by emphasizing situations whose analysis leads the pupils to say the wind `pushes' the objects and, more precisely, that the wind applies forces to the surface areas it catches and that the magnitude of these forces is related to the surface area captured by the wind.

## For the attention of the teacher

In shipping forecasts, the term `wind strength' (given on the Beaufort scale) is used to denote the speed of the wind. In order to avoid misunderstanding, we prefer the term `wind speed' (given in kilometres per hour).

## Examples of results obtained in this initial construction

- Continuous rotation around the horizontal axis;
- interrupted rotation and stabilization in positions which do not indicate the wind direction;

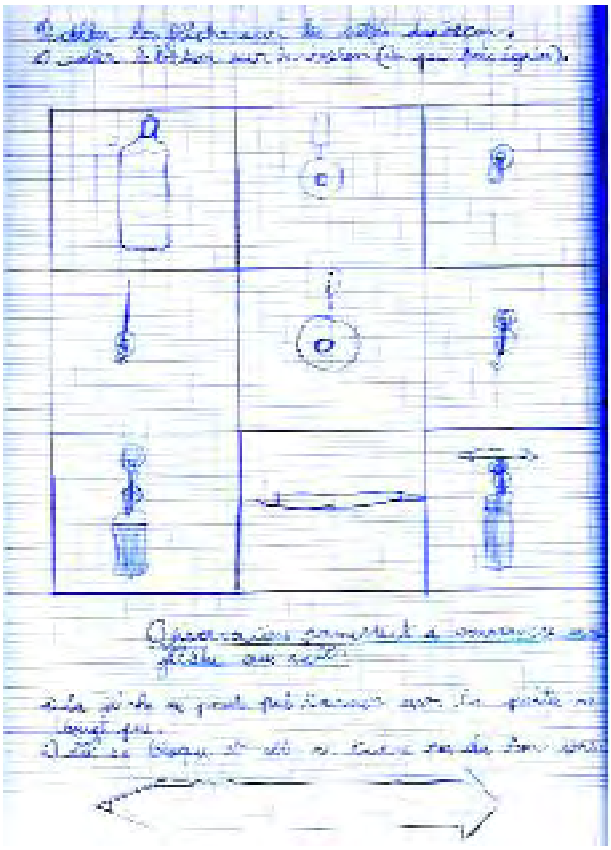
- stabilization and orientation in the direction of the fan (in this case, the teacher asks the pupil to build another, equally efficient form, so as to help him/her to analyse this success).

**Examples of personal records**

*Figure 5.* One might, for example, have the class note all the devices that work and all the devices that do not work. The pupils will then deduce ideas for transformations which they can implement and test. The possible forms of spatial referencing can be introduced at this stage; but this can also be held back until a later lesson.

*<u>"To improve an arrow."</u>*
*a) It must be solid, but mine is not solid.*
*b) It does not move because it is too small.*
*c) It is perpendicular to the wind because the right and the left are almost parallel.*

*<u>"To build a wind vane."</u>*
*"It must be - solid, balanced, large enough.*
*It must have - a light arrow, a truly vertical axis.*
*<u>Materials</u>*
*-paper where the arrow is*
*-scissors*
*-water*
*-screwdriver*
*-pencil*
*-plastic bottle*
*-straw*
*- cork disk*
*-two 30 cm rods*
*-glue*



*<u>How to build it</u>*
*1) Take a plastic bottle (make a hole)*
*2) Make a hole in the cork with a screwdriver*
*3) Push the straw up into the hole from the bottom*
*4) Put a 30 cm rod into the straw*
*5) Make a hole in the cork disk*
*6) Insert the 30 cm rod*
*7) (seal the bottle) put water in and seal it*
*8) (take the rod) take the other 30 cm rod*
*9) Glue the arrow onto the sides of the rod*
*10) Glue the rod on to the rod (almost equal)*

*<u>Observations make it possible to build an arrow which follows</u>*
*1) The arrow cannot turn because the straw does not move*
*2) It becomes blocked and it does not turn in the right direction."*

*Figure 6*

## Lesson 5. Construction of a wind vane

The pupils construct a wind vane which meets the criteria established by the class based on the earlier constructions and experimentation.

**Objective**
Build the object with the predefined characteristics and verify that this object meets the specifications.
Each pupil (or each team) then builds a wind vane which meets the criteria defined by the class. The plans for each project could be given in writing (text and diagrams) and in exchanges organized by the teacher; these plans should be subjected to critical reading and reasoned criticism. This will then check that the pupils' plans agree with the criteria defined.

## Lesson 6. Why do we want to know where the wind is coming from?

The pupils learn from documents about the historical, social role of the requirement to know the wind direction in the past and make comparisons with the present-day requirements. `Why do we want to know where the wind is coming from? What is the purpose?'

**Examples of responses given by pupils**
- To move around with the help of certain devices (yacht, sand yacht..)
- To move around in a safe way (cars, boats, planes with windsocks on airstrips)
- When you go camping, you have to pitch the tent according to the wind
- When you want to have a fire or a barbecue in the garden in Summer, you have to site the fire according to the wind so the cinders do not fall on dry grass and cause a fire and so the smoke does not upset your neighbours.
- When you plant trees, you have to take the dominant wind directions into account
- When the wind is from the North, I know it will be fine, but when the wind comes from the South it brings rain (depending on the region, of course...)

**Documents**
Collection of sayings and various expressions
Documents which will provide an understanding of the historical role of the wind vane
Documents showing the variety of wind vane designs people have thought up and built.
For this lesson, for most of the documentation, one might refer to the resources recommended. One should attempt to be topical as far as possible and also involve surveys conducted among local people (old people, farmers, gardeners, navigators, anglers, firemen, pilots, etc.). It may be easier to undertake this work during an outing. Use of period documents of historical relevance should also be encouraged.
N.B. Texts about the wind can be found in the annex on the CD ROM.

## Lesson 7. How to identify the wind direction?

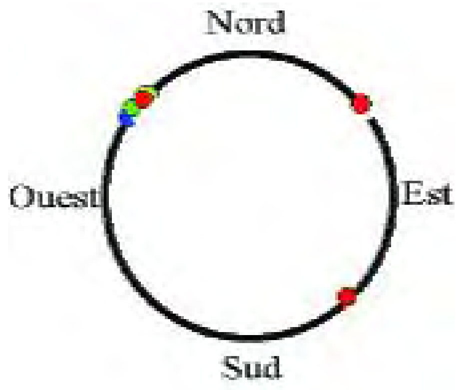
The pupils attempt to identify the wind direction (around the school or on a map or on the test bench) as an an initiation to the concept of local referencing (associated with the walls of the school, for example) and geographical referencing (cardinal points).

This lesson may be introduced during Lesson 3 or independently either during the work on the wind vane or at some other time in the year.
This lesson corresponds to another point of the programme and will not be expanded upon here. However, care should be taken to ensure that each pupil is able to use an appropriate referencing system.

# Lesson 8. What are the dominant winds?

The pupils take regular readings of the direction shown by the wind vane and in this way accumulate a large number of readings in order to determine the most common local wind directions. The teaching of this lesson is linked with the teaching of geography and that of mathematics.

A disc is made showing the different cardinal points. Whenever a measurement is made (once a day, for example) a sticker is placed on the circle at the position corresponding to the direction determined. The accumulations of stickers are associated with the statistical concept of `clusters of points'; the spread of these `clusters' tells us about the variability of the wind and about the uncertainty in the measurements.




*Nord = North*
*Est = East*
*Sud = South*
*Ouest = West*

*Figure 7*

### Examples of records obtained

The accumulations of stickers are used to deduce the dominant winds; here: N-NW (N-NO) and E.

| Day | Wind |
|---|---|
| Monday 2 | N-NW |
| Tuesday 3 | N-NW |
| Thursday 5 | N-NW |
| Friday 6 | No wind |
| Monday 9 | No wind |
| Tuesday 10 | No wind |
| Thursday 11 | E |
| Friday 12 | E |
| Monday 15 | E |
| Tuesday 16 | No wind |
| Thursday 18 | No wind |
| Friday 19 | N-NW |


*Figure 8*

In the figure, a sticker has been placed in the centre when there was no wind. The number of stickers could also be represented by a strip of paper of length proportional to the number of occurrences. Thus, various diagrams could be drawn depending on how familiar the pupils are with a particular representation, presented mathematically or interpreted geographically.

## Conditions for the teaching of the module

This module is based on work undertaken in various cycle 3 classes (CM1/CM2); however, the two questions: `Do you know any objects that can be used to determine where the wind comes from?' and `How is it done?' were also raised by pupils in cycle 2. Comparative analysis of the responses provides a measure of the persistence of certain representations and of the importance of the everyday environment in the development of the latter, for example, `wind only acts on light objects', `wind is produced by clouds'.
This module, which is not a model, is intended to provide examples for each component of the `Basic structure of a module'[3], which will allow the teacher to build up tools that can be transferred to other parts of the programme.
The social and historical dimension of the subject and work on the specific vocabulary may take up a non-negligible time within the module. Putting things into perspective is all the more pertinent because, while the `weather vane' is certainly an object of educational significance, it no longer plays the social role it played in the past. It may actually go completely unrecognized in the modern urban environment. Thus, the ultimate aim is not just to built a wind vane but also to explore all the learning situations made possible by this technological object.

### Materials

- For the class:
Fan, with protective grill
- For each pair or group of pupils:
Straw, pointed meat skewer, paper, cardboard, string, wool, paper fasteners, cloth;
empty cotton reels, pins, cardboard, corks, scissors, glue, Blu-Tack®.
To make the pedestal: a plastic bottle weighted down with sand (or which will be weighted down with water), a wooden or compact polystyrene board.
Other materials will be used, depending on what the pupils propose (and what can be obtained) for Lesson 3.

### Envisaged duration

At least four lessons, at most six or eight lessons.

### Recommended fact sheets

Sheet no. 3, `Air', no. 23, `Electricity', no. 24, `Levers and scales' and no. 25, `Transmission of movements'.

## Taking things further

This module can be seen as an opportunity to introduce other modules or to apply what has previously been learnt. Here are two examples.

### With reference to the module `Levers and scales'

Previous work on levers and scales, enables the pupils to apply concepts associated with levers to the equilibration of the wind vane on its axis. Should a different choice have been made, the necessary concepts, broached by trial and experimentation during the lessons on the wind vane, can subsequently be brought to bear explicitly when studying levers.

### With reference to the module `Is air matter?'

If the module `How do we know where the wind comes from?' is taught afterwards, one might introduce the question `If air is matter, what effects can it produce upon objects when it is moving with respect to them?' It is precisely because air is matter that it is able to act on objects when it is moving. This action is produced by the relative displacement of the air and the object, it is determined by the surface area of the object caught by the wind, whether the air is moving (it is windy) or the object is displaced.

If the module `How do we know where the wind comes from?' is taught first, this can then be used as a starting situation leading to the question `What is wind?' Via comparisons with other means of applying forces to objects the teacher will then be able to guide the pupils towards the questions `What is air?' and `Is air matter?'.

[3] See the section `Reference points for the teaching of a module' in the Introduction.

## Tentative selection of sites

These sites may be useful to the pupils in the documentary research stages, and to the teacher for his/her preparations for the module.

### History of the wind vane

www.ifrance.com/girouettes41/savoirplus.htm
www.autrement-dit.com/automates
www.ville-nogent-le-rotrou.fr/htm/cite/culture/
www.girouettes-argentan.ifrance.com/girouettes-argentan/histoire.htm
www.beaurevoir.be/

### Examples of wind vanes

www.perso.vivreaupays.fr/girouettes/
www.civilization.ca/tresors/
www.ane-art-chic.fr
www.abacom.com/

### Wind vanes and literature

www.chez.com/feeclochette/andersen/coq.htm
www.perso.lub-internet.fr/morgan/bj/girou.htm

### Construction, didactics, weather

www.cskamloup.qc.ca/enseigne/
www.cyberchos.creteil.iufm.fr
www2.ac-lille.fr/meteo-avesnois/instruments/girouette.htm
www.citeweb.net/air-vent/ateliers/girou
www.ac-toulouse.fr/meteo/fpvenecol.htm

It may also be useful to refer to the selection of tools for sciences and technology entitled `101 references' on the CNDP website, www.cndp.fr and to the site www.inrp.fr/lamap.

### Sources

CM1 at the Montaigne school in Sevran
CM2 at the Simone de Beauvoir school in Saint-Fons.

# Water in the nursery school

cycle 1

The topic of water is the guiding thread in this text. The importance of this substance in all scientific domains is evident (water is an important building block of planet Earth and the natural medium in which all living organisms developed). The attraction of pupils of all ages to water is also well known. By virtue of its properties (it flows...), the transformations it undergoes (changes of state) and those which it induces in other substances (mixtures, solutions,...) it lends itself to numerous activities which can help pupils in the initial stages of abstract thinking (the idea of matter and conservation, introduction to the liquid state, ...). The topic of water is dealt without right though the schoolyears. After an initial, predominantly sensory approach at the nursery school, learning continues in cycles 2 and 3 where the first properties are presented. One should not lose sight of the fact that the study of the properties of water continues right into higher education.

The teaching at the start of cycle 1 is often based upon small groups using familiar materials. The principles governing the organization of small scientific study groups aim to go beyond simple free discovery (section, `Organizational principles for scientific activities'). The section `Small groups working on the topic of water' develops an example of the progression of these small scientific study groups in the first year of nursery school. Progressively, the child acquires skills that make it possible to think of courses consisting of lessons which follow one another and are joined up to each other. Two examples show how to hold a scientific questioning session and how to go about building up scientific knowledge in four or five lessons. The first example is tailored to the first or second year of nursery school (section, `Problem situations in the first or second year of nursery school concerning the transportation of water), the section is specific to the third year of nursery school (section, `A course for the third year of nursery school: introduction to the phenomenon of solution').

Taking into account the special nature of nursery school education, the plan for this module is slightly different from the general scheme adopted for the other modules.

## Position in the programmes

| Extracts from the programme | Extracts from the application document |
|---|---|
| **Sensory discovery**<br>- Exploration of the characteristic tastes and smells of certain foods.<br><br>**Exploration of the material world**<br>In this way, the child can practise modelling, trimming, cutting, dividing up, mixing, assembling, fixing, transporting, decanting and transforming in dealings with many varied materials.<br>In comparing water from the tap, rain, snow and ice, he/she begins to develop a first, very modest, level of abstraction and to understand that these diverse realities relate to single substance: water. He/she compares mixtures: syrups, paints.<br>This exploration leads to dialogues with the teacher which allow the child to identify, classify, arrange and give a name to materials, objects and their qualities. | Whatever project is under way, whether or not it is predominantly scientific, the use of varied materials is a required element. The teacher seeks to develop a well-considered attitude towards their choice. Examples abound. Dressing up in clothes designed to protect against rain (for real or in play) leads to thoughts about permeability and impermeability and results in the comparison of different cloths from which a selection must be made.<br><br>It is also appropriate to grasp or provoke opportunities in which pupils will act on matter to modify its properties depending on their project. This is the case in culinary activities where one has to decide whether to add salt or sugar to modify the taste of a dish, flour or water to change the consistency of a paste, etc. As well as being of interest for modelling, the making of salt pastry offers the opportunity to experience the effects of correct and incorrect proportions in mixtures. Mixing of paints leads initially to fortuitous results which, however, can be objectivized using a more methodical approach. |
| **Discovery of the world of objects, safety education**<br>The gaining of an awareness of risks occupies an important position in this sphere of activities:<br>- Risks of the immediate everyday (dangerous objects and toxic products) or the more remote environment (major risks). | Numerous opportunities can be grasped or provoked, without necessarily giving rise to an elaborate project. However, beyond the simple observation of these situations, there is a need to think of how they can be exploited. Examples: during swimming lessons, the pupils experience differences between movements in the air and in the water. On return to the classroom, more systematic trials may be undertaken involving the movement of different objects of different shapes in bowls of water. |

This initial knowledge marks the beginning of learning which will be pursued in subsequent schooling.

- In cycle 2: water (liquid) and ice are two states of a single substance.
Water is liquid at a temperature greater than zero degrees at a temperature lower than zero degrees.
Matter does not appear and does not disappear, even though it may sometimes not be perceptible.

- In cycle 3: the main objective is to consolidate the knowledge of matter and its conservation. States and changes of state of water. Mixtures and solutions.

## Small study groups working on the topic of water - a module for the first year of nursery school

The number of pupils will vary according to the materials and the equipment. On average, four pupils around a tank of water or a large bowl seems reasonable.
Each lesson lasts around 45 minutes, including an introduction, tidying up and an appraisal, which is equivalent to 15 minutes of effective experimentation.
The introduction and the appraisal are undertaken with the whole class. The times given over to these must necessarily be short, although they recur regularly as the exploration progresses. The pupils take part in them, making different contributions which evolve as the lessons progress. The repetitions and the verbalization of what they have already experienced or what they will experience later contribute to the processes of both linguistic and scientific learning.

| Lessons | Starting question | Main attitudes sought | Activities conducted with the pupils | Knowledge, facts and know-how brought into play |
|---|---|---|---|---|
| Lesson 1 | What happens when I play with water? | Safety, cleanliness. respect for others and for materials | Sensory discovery, play with the hands, with various receptacles (decanting, immersion of receptacles...) | Description of actions undertaken. Introduction to the properties of the liquid state: `it flows, it is wet, it overflows, it spills... |
| Lesson 2 | What is water for me? | Safety, control of actions to work with small quantities | Comparison of liquids, use of the senses to analyse them and distinguish between them | Criteria for recognizing water: colour (it is not blue!), opaqueness, transparency, the smell and possibly the taste of water. Acquisition of a method. Prevention |
| Lesson 3 | What noises does water make? | Respect for conditions required for listening | Analysis of an audio document, identification of various water noises in everyday life and in nature. | Auditory discrimination. Initial introduction to the characteristics of a sound. |
| Lesson 4 | What does water do with other materials? | Search for rigour, perseverance | Experimentation with mixtures using identified materials. Classifications | Description of the mixtures observed. Introduction to the concepts of solution, measurement and proportions. Acquisition of a method. |
| Lesson 5 | How do you make ice cubes? | Formulation of hypotheses, anticipation of a result | Sensory discovery of ice. Making of ice cubes using various moulds. | Introduction to the change between solid and liquid states of water. Introduction to the differences between liquid and solid state. |
| N.B. Lessons 1 and 2 are autonomous. Lessons 3 and 5 are `semi-directed' , possibly with the help of a classroom assistant or regional ancillary staff in nursery schools (ATSEM). Lesson 4 is directed by the teacher. | | | | |

## Lesson 1. What happens when I play with water?

### Materials

- Transparent water tank, various receptacles of different sizes and shapes;
- spoons, plastic forks, dolls' clothes;
- funnels, sieves;
- waterproof aprons, sponges, floorcloths.

### Instructions

"Play with the water; try out all the materials you have; stay above the tank, use the sponge if necessary."

### Linguistic skills

Description of actions (fill, empty, decant, overflow, sponge down...) and of states (dry, wet, humid,...).

### Scientific skills

- Introduction to the liquid state of water: it flows; it passes through the sieve, through the floorcloth
- Explanation of the movements of water (in preparation for the idea of conservation, it is important to follow the movements of water to accustom the pupils to the fact that it does not disappear[1]): the water is in this bottle, I decant it into this bucket; I have mopped up the water with the sponger, when I press the sponge, the water runs out; etc.

### Links with other situations experienced at school or at home

The teacher encourages the pupils to establish relevant links ( a glass of water spilt during a meal which has to be mopped up, rain which makes you wet and passes through clothes...)

### Possible extensions

Discussion of the problems encountered (it is difficult to hold water in your hands; it is difficult to play without getting wet, without making the floor wet) leads to possible extensions.
What can you use to protect yourself with when you are playing with water? (concepts of permeability, impermeability; testing of different cloths)
What can you use to wipe the floor with? (concept of absorption, testing of different cloths, of different papers).

## Lesson 2. What is water for me?

### Introduction to the lesson: prevention, health education

The products prepared are not toxic and are measured out in small quantities. This is explained to the children. But they must also know, as the teacher will tell them in this introduction, that they must never taste something they do not know.

### Materials

- Several small bottles containing different liquids of different consistencies, which may be transparent, opaque or coloured (tap water, fizzy water, water and sugar, water and bitter-almond extract, water and medicinal mint spirit, water and lemon, water and salt, water and vinegar, water and aniseed extract, water and oil,...) and one or two bottles of tapwater;
- blue stickers and red stickers;
- transparent cups, buckets;
- a jug filled at the tap by the children themselves.

[1]In cycle 1, only the case in which the phenomenon of evaporation is not involved is considered.

### Instructions

"Find the tapwater among the small bottles by using small quantities of liquid and comparing each liquid with the water in the jug. If it is not the same, stick a red sticker on the bottle; if it is the same, stick a blue sticker on the bottle."

### Linguistic skills

Description of the appearance (colour, presence of bubbles, clear, murky, thick, fluid,...) the flavours (sugary, salty, sharp, bitter, acid,...), giving off an odour (it smells, it does not smell of anything, it smells good, it smells nasty).

### Scientific skills

Introduction of a procedure: look (which is sufficient to eliminate certain liquids), then smell, and finally taste. Often there is no need to touch.

### Links to other situations experienced at school or at home, safety education

Listing of receptacles containing liquids, found in the home, which one should not taste (washing-up liquid, detergent, domestic cleansing products, products for the garden,...). Interpretation of labels and signals warning of danger.

### Possible extensions

Games to identify liquids based on the taste, with eyes blindfolded (cordials, milk, water,...)

## Lesson 3. What noises does water make?

### Materials

- A recording, made for this purpose in the school, water noises familiar to the pupils (10 minutes). It is of interest to include `intruders' (birdsong, human voice imitating the sound of water, sound of a musical instrument...) and repetitions of the same noises with different sound intensities;
- photographs or drawings illustrating the different situations recorded (shower, tap, toilet flush, washbasin, watering can, hosepipe, filling of glasses...);
- photos or drawings illustrating water not included in the recordings (torrent, sea, rain, fountain,...);
- photos or drawings of `intruders', evoking the sound of water (piano, harp, bells, birds, ...);
- a box for the photographs and the illustrations.

### Instructions

`Listen to the tape and classify the photographs or illustrations. Place those you can understand in the box and leave those you cannot understand on the table'.

### Linguistic skills

Characterization of a sound: loud, soft, high-pitched, low-pitched, short, long...

### Scientific skills

The characteristics of a sound are introduced in this way: intensity, pitch, timbre.

### Possible extensions

Use of recordings of less familiar noises (torrent, waves,...). Possible imitations. Musical instruments (water maracas, striking of glasses filled with different amounts of water). Listening games Comparison of the sound of a droplet falling on a lid, on crockery or on a different material. Imitation of the sound of water: sound effects.

## Lesson 4. What does water do with other materials?

### Introduction to the lesson
Different products mix more or less well with water. Everyday situations experienced by the child, preferably at school (meal, cookery, washing) are brought up: The teacher asks, `What happens when you put sugar (sand, sweets, letuce,...) into water? The pupils answer in their own words: `It disappears, it melts, lettuce does not melt, etc...'.

### Materials
- 4 small jugs full of water;
- 12 to 16 baby food jars with lids;
- 4 tanks or shallow basins or serving trays;
- 4 teaspoons, 4 small ice-cream spoon spatulas;
- adhesive labels and a ballpoint pen
- solid and liquid materials: flour, sugar, cereals, sweets, cakes, ink, paint, chalk, straw, paper, earth, sand, glue, grass, bark, instant coffee, chocolate, milk, oil, greasy chalk.

### Instructions
`Mix a solid or liquid material with water in a small jar. Close the jar securely before shaking it. Tell me the name of the material you mixed with the water so that I can write it on the label. Try with other materials, one at a time. You can put a lot of material in one small jar and a small amount in another. You must not taste any material or mixture.

### Role of the teacher
The teacher guides the pupils via his/her questions (do the same mixtures give the same results?). He/she helps them to think things through, encourages them to proceed with care and to count the number of spoonfuls of the product they add to the water.

### Linguistic skills
One particular product mixes, another does not[2]. Appearance of the mixture obtained: murky, clear, ...

### Scientific skills
Initial introduction to solution and saturation. Gaining an awareness of the constraints associated with reproducibility (the same causes produce the same effects); need for careful measuring out. introduction to measurement and to measuring out.

### Possible extensions
When one follows a recipe (cookery, salt pastry, preparation of inks for the visual arts...) one has to respect the quantities indicated.

## Lesson 5. How do you make ice cubes?

### Introduction to the lesson
What happens when you take ice cubes out of the refrigerator? What can you do with these ice cubes? How do you make them?

### Materials
- A stock of ice cubes (only to be taken out slowly);
- various receptacles with which to make moulds;
- modelling clay (for making moulds or moulding in the receptacles).

### Instructions
"Take out the ice cubes, play with them using your hands and the receptacles."

[2]In the first year of nursery school, it is premature to wish to introduce the term `dissolve'.

A little later, after the free-discovery phase, the teacher asks, `Can you make ice cubes? With what? Can you use the water from the ice cube which has melted to make another ice cube?'

### Role of the teacher
- To solicit hypotheses and anticipations, the teacher asks,
`How do you make ice cubes?' `Will they all have the same shape?'
- To tailor the instructions to the childrens' capabilities. Many children in the first year of nursery school are not able to make moulds out of modelling clay. It is suggested that they use other moulds. They are also encouraged to fill a mould with modelling clay to help them to understand later that an individual mould leads to a unique shape, whether it is filled with water or with modelling clay (telltale shape).
- To remark upon the transformation from ice to liquid.

### Linguistic skills
Ice cube, ice, to melt, to freeze.

### Scientific skills
Initial introduction to the changes of state of water and their reversibility.

### Possible extensions
Snow: it turns into water, but it is not possible to turn the water into snow again at school.

# Problem situations in the first or second year of nursery school concerning the transportation of water

When small exploratory (free and guided) working groups are set up regularly in order to teach behavioural skills, pupils, even in the first year of nursery school, acquire the right attitude for experimentation and research. Having acquired this (the condition is important), they can be confronted with situations, which we shall call `problem situations' here: When a question is raised, the pupils move forward by trial and error, they carry out research and experiment to find the best answer. It is the experimental activity which, first and foremost, validates the methods thought up by the pupils.

Each of the lessons described below involves the resolution of a problem situation concerning the transportation of water from the sink (or from a large basin) to smaller bowls. The instructions are formulated by the teacher (at the start) and then by the pupils who, very quickly, understand the logic of the sequence. After an activity phase, the lessons end with an appraisal. In each case, pupils' prerequisite knowledge will be clearly stated. Finally, each lesson is extended to allow the children to draw and label their individual drawings (the labels are dictated to the teacher). It is interesting to take regular photographs of the pupils carrying out their experiments, since these can be used to support language lessons which may take place at some other time in the day. The diagrams, to which any photographs taken during the activity are attached, are collected together in a large experiment book, which is put together collectively and made available to the pupils who always immerse themselves in it with great interest. These very important extensions, which may take place systematically and about which the parents may be informed, will not be mentioned in the description of each lesson.

## Using the hands
It is very important for the children to have physical contact with water. The experiments are carried out directly from the very start.

### Instructions
"Transport the water which is in the big sink, to small empty bowls several metres away. "

### Examples of behaviour observed
The students are often thrown off balance by the absence of materials. At first, some of them are afraid to touch the water. They do no know how to go about it. They become bolder, take the water in the hollow of their hands and run so as to lose as little as possible. They move the bowl nearer the sink. Some of them cooperate, one holding the bowl over the water and the other filling it with his/her hands.

### Appraisal, structuring
The child talk about their actions and their difficulties: `I put my hands like this', `It's difficult'. They formulate explanations for their difficulties: `The water goes away', `The water flows', `There are holes in our hands'.

## Using materials
The set up and the instructions are identical to in the previous activity, but the pupils can now use various more or less appropriate tools: watering cans, bottles, glasses, a toy tea set, sieves, bottles with one or more holes. The list is not exhaustive. The pupils may go and look for other utensils which they think of.

### Examples of behaviour observed
Some pupils persist for a long time in using tools which are not very effective (receptacles which are too small). Others try anything they can get their hands on, apparently without thinking. Others move quite quickly towards optimal methods (receptacles of the right size). Some pupils take their bowl and go to dip it in the sink.

### Analysis, structuring
The pupils describe what they have done: `Stopped the hole in the funnel with a finger', `Paired up to stop the holes in the bottle', `Ran, so that the water did not have time go away'.
Then the teacher engages them in the formulation of the reasons why some tools are more effective than others: `Some tools don't work well, they have holes'. They name, describe and compare the tools: `You can stop the hole in the funnel, but you can't stop all the holes in the sieve'.

## Sorting the tools
From the start of nursery school, it is customary to accustom the pupils to using symbols to denote a success or a failure. They do the same thing here with the tools made available to them for transporting the water.

### Instructions
"Try to transport the water with an object. Put those which work into a bowl, and those which do not work into another bowl."

### Structuring
Various documents, appropriate to the age of the pupils and to the time of year, can be used to keep a record of the tests performed.
- Selection of photographs: creation of a frieze of `things which work' and `things which do not work'.
- Individual documents: based on pictures of the objects (photographs, drawings), labelled with the appropriate symbol, (A possible variation is to cut out and stick in the right column).

## And with less water...?
After the many experiments of the third stage, the children have learnt how to choose the appropriate materials for transporting water. Consequently, they rapidly fill the small bowls and the water level in the big sink visibly decreases. This presents a new problem: the tools which previously worked the best (bottles, watering cans), become quite impractical.

### Instructions
The problem is formulated with the pupils.
"When we have a lot of water, we empty the sink with our tools. Now we have almost no water left and some tools no longer work. How do we finish emptying the big sink with the tools we have?"

**Examples of behaviour observed**
The pupils find solutions**:** they take smaller objects which can still be filled; some use small receptacles to fill the large ones**.**

**Appraisal, structuring**
The pupils name the tools which still work.
The teacher guides them towards more complete and more complex formulations in terms of language. They explain why the large receptacles no longer work: `the bottle can't go in any further because it touches the bottom'. They justify their choices: `I chose the small spoon because the watering can doesn't work'. They formulate comparisons: `the spoon works better than the watering can'; `the spoon works better than the watering can because it is smaller'.

Through these latter formulations, the pupils are introduced to the concept of capacity.

## Only a few traces remain

The previous stage and its conclusion serve to introduce the following problem**:** `what can one do when there is very little water left and no tools work any longer'.

**Instructions**
"Remove all the water from the big sink and transport it into the small bowls."

**Materials**
In addition to the receptacles used up to this point (which are retained in order that the pupils may try them none the less), various more or less suitable objects and materials (floorcloths, sponges, absorbent paper, cardboard, various papers, kitchen foil, handbrushes, scrapers) are proposed.

**Examples of behaviour observed**
Some pupils ignore the materials and use their hands. But through everyday experience they readily move towards sponges and floorcloths. The teacher encourages comments and comparisons with familiar experiences. He/she leads them to try the other tools and the other materials. He/she ensures that the pupils squeeze the various materials and see the water come out. This is important so that they understand that water is absorbed by the materials.

**Appraisal, structuring**
The pupils name the different tools and describe their actions verbally: sponging, squeezing...
They describe what happens: `the water goes into the sponge; it comes out again when you squeeze it'. They explain why the material is suitable or not: `The water doesn't go in'; `The water damages the paper".
These activities give the pupils an opportunity to familiarize themselves with the concept of absorption. However, it seems premature to want to make them use the scientific vocabulary (the sponge absorbs the water).

## Sorting the materials

The children have already sorted the different objects. Here, they sort the different materials (absorbent or not).

**Instructions**
"Try to transport the water using one of the materials. Put it in the right bowl according to whether it works or not."

**Structuring**
Reference can be made to the paragraph dealing with a related question (sorting the tools, pg. 118), where the choices to be made are of a similar nature.

### Possible extensions

- Cooking activity: make a tabbouleh to show the class some foods that swell up under the action of water: `the water goes into the semolina and does not come out again'.
- Compare the transportation of water and that of pebbles: the most approp riate tools are not the same. The pupils gain a first experience of the differences between solid and liquid state.
- Relate the size of the receptacle to the effort needed and the number of journeys taken. Children learn that `With a large receptacle, it is heavier, but you make fewer journeys; with a small receptacle, it is lighter, but you make more journeys.
- Introduction to measurement, to answer questions such as `how many receptacles are needed need to fill a bowl?', etc.

## A module in the third year of nursery school - introduction to the phenomenon of solution

At the start of nursery school a child knows that an object which disappears from his/her sight has not ceased to exist. He/she may, for example, throw a tantrum to be given back a toy that has just been put away. It is as though he/she were capable of the following reasoning: `I know that that toy still exists: it has not vanished, even though I cannot see it any longer'. Of course the child does not really follow this reasoning in a conscious way. However, he/she can be said to have mastered the idea that the object is permanent. He/she cannot put this into words, but his/her actions bear witness to the fact. We shall say that the child is using or implementing a first conservative reasoning (whether consciously or not). The term *conservative* refers to the permanence of matter and its conservation, a fundamental property in physics and classical chemistry (as Laplace said, `nothing is lost, nothing is created').

Objects are only particular cases of the numerous forms which matter can take. They are visible, and have a characteristic shape which changes little, if at all. When they are put away in a cupboard they retain all their characteristics. In this module, we are interested in the phenomenon of solution. When it is dissolved, matter changes its appearance, a sugar lump dissolved in water cannot be seen anymore. However, the water is transparent, you can see through it. Why can you not see the sugar? Has it vanished? An adult knows that a dissolved substance has not vanished, even though it is no longer visible. His/her cognitive system has a perfect grasp of the conservation of matter and is aware of the general validity of that principle, however things may appear. By the age of 4 or 5, the child has learnt the principle of conservation in certain particular cases, notably when it does not cast doubt upon his/her immediate perceptions. But it is still not a general property for him/her.

To help pupils to progress to a grasp of conservation, even when appearances seemingly contradict it, the idea is to exploit a number of situations in which the senses (sight, taste) can still be relied upon. The taste of sugared water is an indicator (but not a proof) that the sugar has not disappeared. Lesson 4, `What does water do with other materials?', presented in the module in the first year of nursery school, provides an example of the exploitation of that idea.

The module presented here goes in the same direction, relying in this case on sight. As the main material, it is proposed to use sweets (well known to children of this age) with a chocolate centre, coated with sugar (with a white colour) and then with a glazing whose colour may vary (in what follows, these will be referred to as `coated sweets' or simply `sweets'). When this external coloured coating is dissolved its colour is transmitted to the water, and it is this which provides the basis for the various activities described below which, in a summarizing phase, are related to the behaviour of other substances (in particular, salt and sugar, as experimented with in the small study group phase). Sugar, salt and the coating of the sweets all dissolve in water; the sugar and the salt disappear from sight but their taste remains present; the sweet coating disappears (it can no longer be distinguished as such) but its colour remains present. The sense which can be relied upon (taste, colour) and the parallelism established between the different substances can contribute to the beginning of the construction of the concept of solution.

**Precaution**
The coated sweets used are food products. The substances which dissolve in water go off (moulds quickly appear). Thus, one should not seek to keep the solutions obtained, even overnight. Cleaning must be systematically carried out at the end of each activity.


## Scratch the sweets to make them white

The coated sweets have their colours removed by being passed under water and are dried before the children arrive. They are negligently left lying on a table.

**Example of procedure**
The pupils discover the sweets and react immediately: `They are white; they aren't coloured any more'. The teacher looks dismayed: `Someone has stolen the colour from the sweets! The pupils are not taken in and immediately provide an explanation: `When you suck them, they turn white...'.

The teacher explains that he/she has not sucked them (that would not be hygienic) and, taking an enigmatic attitude, he/she challenges his/her pupils to come up with ideas for removing their colour. Hypotheses are put forward. Examples: spit on them; scratch them, rub them and wash them with water, soap or washing up liquid. Everyone agrees to rule out certain solutions (spit on them) and a decision is taken to test the others, beginning with the idea of scratching the sweets. It remains to choose what to scratch them with. Various proposals are accepted: the nails, scissors, knives and forks from the cookery corner, screwdrivers or graters from the do-it-yourself corner.

The pupils get down to business. The teacher joins them and also scratches the sweets. He/she solicits reactions and encourages discussions among the pupils.

Example of discussions:
- “It's difficult”;
- “The colour isn't going much at all”;
- “I've got there, I can see a bit of the white”;
- “Mine is broken. You can see the chocolate and the white”.
- “The colour is going on to the table”.
- (Teacher) “Yes, the sweet debris is going on to the table. What colour is it?”, etc.

The teacher helps to improve the formulations (it is not the colour that is falling on to the table, but the coloured debris) and to the vocabulary (debris, dust, pieces, powder,...).

**Outcome**
The pupils, possibly guided by the teacher's questions, should succeed in formulating a phrase describing the movement of the material: `The coating of the sweets is broken by scratching. The small coloured pieces fall on to the table'.

## Wash away the colour, but what with?

It is now time to try out the second idea: to wash away the colour with water, soap and washing-up liquid. The activity is undertaken in a specially prepared `water corner'. The teacher provides the soap and the washing-up liquid when the children ask for them, and ensures that the solutions remain dilute.

### Example of procedure

The teacher leaves the pupils to proceed by trial and error. He/she does not seek to make them adopt a methodical procedure which would be premature in the initial period of the small working group. He helps them to identify the different phases of the loss of colour: the coloured external coating dissolves, followed by the white part. If the activity is continued, it ends with the centre of the sweet, consisting of chocolate, dissolving of which immediately gives the water a dark brown colour.

All the pupils manage to wash the colour off their sweets. They also notice that the water loses its transparent colour. `It gets very dirty'. Eventually, all the colours dissolve in the water giving it an unattractive brown shade. The pupils enjoy this activity and, quite normally, experiment completely unmethodically. They try and mix all the products to the extent that it is impossible to tell whether one solution is more effective than another. Thus, a decision is taken to set up three work stations in order to carry out new tests in a more methodical manner. At each station, a different liquid is used to dissolve the coloured coating: water at the first station; soapy water at the second station and washing liquid at the third station.

### Outcome

The pupils describe their observations using an appropriate vocabulary (coloured, decoloured): the sweets are decolorize; the water is coloured; the wa ter is coloured brown. Finally, they come to establish the correlation between the decolorization of the sweets and the coloration of the water: the water is coloured because the sweets have lost their colour.

## Colour the water a colour chosen in advance

### Example of procedure

The teacher recalls the previous activity and emphasizes the colour of the water. Where does its brown colour come from? There is no lack of opinions: `It is dirty because we didn't wash our hands', `it's the chocolate that's in it', etc. At this stage the pupils do not, in general, understand that the brown shade comes from the mixing of all the other colours. The first step is to test the different hypotheses.

Everyone washes their hands.

The sweets are removed as soon as they lose their colour, before the chocolate is reached.

The water obtained is clearer, but it still has a brown colour.

The teacher shifts the problem slightly: `And if you wanted to obtain yellow water, how could you do it?'. The answers evolve easily towards the desired idea: `You would have to use yellow sweets only'.

The sweets are sorted according to their colour and the pupils go to wash them in a small transparent jar. These jars are collected together at the end of the activities so that the initial idea can be validated.

### Outcome

The outcome of the previous day is recalled: the sweets lose their colour and at the same time the water becomes coloured.

It is extended: if the sweets are red, the water is coloured red.

When sweets of all colours are mixed, the water is coloured brown.

In the third year of nursery school, the children are generally able to relate this idea to mixtures of paints: by decolorizing yellow and blue sweets one might perhaps obtain green water. Of course, it is important to test these hypotheses if they arise.

## Comparison of sugar, salt, sweets and other materials

While working in small groups on water and under guidance at the same time, the pupils mixed various substances with water. They observed that some `mixed'[3] whereas others did not. With the naked eye and through a magnifying glass they watched small pieces of sugar `disappear' in the water. Of course, they were invited to taste the water to see that the sugar, although invisible, had

[3]Term used by the pupils to mean `dissolved'.

not vanished. But one occasion is never sufficient to learn something on a lasting basis. The activities performed with sweets provide the opportunity to return to the idea of solution, to enrich it with other examples and to put a better structure upon it.

### Example of procedure

The teacher proposes various materials contained in appropriate receptacles: salt, powdered sugar, a coated sweet, powdered milk. Each pupil also has small transparent receptacles containing water. The pupils begin to scratch the sweet so as to obtain the coloured debris. They then mix each substance with the water and observe what happens. The teacher encourages them to describe everything: `What is the same, what is not the same?'

### Outcome

The discussions and the reformulations result in the following ideas.
At the start, the grains of salt, the sugar granules, the coloured debris from the sweet and the milk powder can be seen. Then they can no longer be seen.
For the sugar and the salt: they can no longer be seen, but if one drinks the water one can taste them.
For the sweet debris: the colour can be seen and if one drinks there is a slight taste.
For the powdered milk: the white colour can be seen.
It is difficult to go further and try to convince the pupils about the conservation of matter. At nursery school, the importance of immediate perception wins the day over any other argument. The cognitive construction of the conservation of matter will be pursued at elementary school. The dissolved substances could, for example, be recovered by evaporation. One can only hope to have instilled in the pupils the stable conservative reasoning which will be exploited at Collège by the end of cycle 3.

## Conditions for the teaching of the module

The general objective is to succeed in developing the attitude of the researcher in the pupil. For this, the form of the activities will evolve over the year so as to progressively develop the essential behaviour needed to take part in truly scientific small study groups with all the required autonomy.

### Evolution of the forms of activity

Free exploration: exploration guided by the teacher's instructions regarding the task to be performed and the observations to be made; experimental attempts to explore more precise properties; confrontation with research situations, necessitating trials, errors and communication between pupils.
The behavioural objectives are principally developed through small groups working in free exploration. The scientific objectives are more effectively pursued later through more open activities (experimentation and research situations). The progression is designed to take place over the year. It is possible to involve the pupils in research situations from the first year of nursery school (see, for example, the section `Problem situations in the first or second year of nursery school concerning the transportation of water').

### Benchmarks for the behavioural objectives to be developed

Respect for comrades and the group organization. Respect for the rules of hygiene and safety. Control of ones own actions. Autonomous evolution in the environment prepared and marked out by the teacher. Acceptance of a return to the learning process; continuation until the end of the task; acceptance of a need to start again; paying attention; search for quality. Acceptance of others, communication, ability to make suggestions and take things into account; demonstration of findings, ability to give and accept help...

### Role of the teacher

Teacher is not constantly present in each of the small working groups at the same time. The small groups for free exploration and then guided exploration require a lesser presence on his/her part. At the beginning of the year when the children are less autonomous, these small working groups are used most opportunely. When the students are confronted with more complex tasks, and then with situations in which they need to research and experiment, the presence of the teacher becomes increasingly necessary to guide them and relaunch the activity based on new questions. If the pupils have acquired a sufficient autonomy in these first periods of the year, the teacher will be able to set up small working groups operating autonomously while he/she drives forward and progresses a particular situation.

**Exploitation**

The lessons end with a period of analysis, in which findings are exchanged and the different solutions put to test in experiments are compared. This is an important time for language skills (acquisition of a more precise vocabulary, more accurate formulations). The thing young nursery school pupils find easiest is the verbalization of their actions (I did this, then that...). It is useful to help them to become decentralized and to formulate more general propositions about an object, a substance, a phenomenon or a property of water (water is like this; it behaves like that...). As a complement to the activities undertaken, verbalization is a necessary part of the early acquisition of scientific skills and knowledge. Visual and written records (posters, photographs, drawings, texts dictated to an adult,...) extend and complete these periods of analysis and also contribute to the learning process.

**Precautions**

Safety requirements demand particular vigilance by the teacher who must, in particular, warn the pupils of the risks inherent in experimentation with water in basins, with ice cubes (care should be taken to ensure that the temperature is not too low) and with non-consumable products.

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Work trialled at Issy-les-Moulineaux in the Acacias nursery school, at Vaulx-en-Velin in the second-year class of the Martin Luther King nursery school and at Seynod in the third-year class of the La Jonchère school.

Some of the work was inspired by the following websites: www.ac-grenoble.fr/savoie/Disciplines/Sciences/Index.htm and www.innopale.org

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