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Early Science Education: Exploring Familiar Contexts to Improve the Understanding of Some Basic Scientific Concepts[1]

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SUMMARY *This study rests on the belief that Science Education is a fundamental tool for global education and that it must be introduced from the early years in formal schooling as a first step to a scientific culture for all. The question is to make clear what to learn and how to teach in a way that is both motivating for children and conceptually sound. A didactic strategy for developing the learning of concepts such as dissolution and floating in water was conceived as part of an in-service course involving 90 Portuguese primary school teachers. About 1800 pupils participated in the validation of that strategy in 90 classrooms.*

The adopted strategy was based upon an experimental work approach, using everyday life contexts which are familiar to children (for example, to suck sweets and to observe the behaviour of fruits and vegetables in water).

The main steps of such a methodology, as well as some child learning outcomes, are here presented and discussed.

RÉSUMÉ *Cette étude postule que l'éducation scientifique est un instrument fondamental pour l'éducation dans son ensemble et qu'elle doit être introduite dès les premières années de la scolarité en tant que première étape d'une culture scientifique pour tous. La question est alors de savoir ce qui est à apprendre et comment l'enseigner d'une façon qui soit motivante pour les enfants et conceptuellement adéquate. Une stratégie didactique, visant l'apprentissage de concepts tels que la dissolution dans l'eau ou la flottaison, a été conçue dans le cadre de la formation continue de 90 enseignants de l'école élémentaire. Près de1800 élèves de 90 classes ont participé à la validation de cette stratégie.*

La stratégie adoptée s'appuie sur une approche expérimentale utilisant les contextes de vie quotidienne familiers aux enfants (sucer des bonbons et observer le comportement des fruits et des légumes dans l'eau).

Sont ici présentés et discutés les principales étapes de cette méthodologie ainsi que quelques résultats concernant les apprentissages des enfants.

ZUSAMMENFASSUNG *Diese Arbeit hat als Voraussetzung, dass wissenschaftliche Bildung ein grundlegendes Bestandteil der Bildung für alle ist, und dass sie schon in den ersten Jahren der Schulzeit eingeführt werden soll. Die Frage ist zu klären, was lernen ist und wie es den Kindern in einer motivierenden und nützlichen Art beizubringen ist. In dieser Arbeit wurde eine didaktische Strategie für das Lernen der Begriffe, 'Auflösung' und 'Schwanken' im Wasser entwickelt, die im Unterricht von 90 Grundschullehrern in 90 Klassen, in welchen ungefähr 1800 Schüler teilgenommen haben, bestätigt wurde.*

Die Strategie benutzte eine experimentelle Perspektive, die vertrauliche Zusammenhänge für die Kinder anbot (Bonbons zu lutschen, das Verhalten von Obst und Pflanzen im Wasser zu beobachten).

Die methodologische Etappen werden hier vorgestellt und diskutiert, sowie die Belege, dass die Kinder gelernt haben.

RESUMEN El estudio parte del supuesto de que la educación en el área de ciencias es un componente fundamental en una educación que quiere ser global y que, por tanto, se debe introducir desde los primeros años escolares como el primer paso para conseguir una cultura científica para todos. La cuestión básica a clarificar es qué se debe aprender y cómo se puede enseñar a los niños de una forma que sea simultáneamente motivadora para los niños y conceptualmente sólida.

En un programa de formación en servicio en el que participaban 90 profesores portugueses de escuela primaria se desarolló una estrategia didáctica para el aprendizaje de conceptos como el de 'disolución' e de la 'flotación en el agua'. Posteriormente tal estrategia fue validada a través de su puesta en práctica en 90 clases con la participación de alrededor de 1800 niños.

La estrategia utilizada estaba basada en un enfoque de trabajo experimental usando los contextos de vida cotidiana que son familiares a los niños (tales como chupar caramelos y observar el comportamiento de las frutas e de los vegetales sumergidos en el agua).

Keywords: Primary school science; Fair-test experiments; Familiar contexts; Dissolving; Floatation.

Science education as a component of global education for citizenship

Social changes that are occurring on a world scale at the end of this century have effects on economic and organisational life, which inevitably have an influence on the ways and means information and knowledge are disseminated. It is this increasing dissemination which today allows us to have a greater and more global awareness of the world, of societies and of their differences and contrasts. However, it also allows us to be aware of the similarities as far as basic educational needs are concerned for better management of the available resources and the search for solutions to international problems. Included in these problems are the overpopulation of the planet, the scarcity of food, the over-exploitation of energy resources and of the sub-soil, the spread of epidemics, the degradation of the environment, the drug trafficking and so on. These problems require countries to act in concert to maintain equilibrium in the world (PNUD, 1999; 2000).

The resolution of these problems, despite the fact that they rest on economic interests and political decisions, cannot fail to take into account the scientific knowledge which exists today about their possible causes and consequences. Nevertheless, science itself does not always pursue the solution of these problems as its most important concern, because scientific knowledge increasingly depends on finance dispensed by people who are not always concerned only about the truth or what is good.

Indeed, scientific-technological development is neither linear nor independent of the dominant social and ethical values at any moment in time. Similarly, a scientific view of the world is not the only one possible. However, in order to solve a great number of questions the importance of scientific knowledge cannot be ignored. Only science can provide a basis from which the effects of technology on the environment can be evaluated; only science can help to find solutions for the safety of the planet; finally, only scientific methods will allow sound judgements to be made on questions that are international, national and part of people's daily lives (Rutherford & Ahlgren, 1990; Hodson, 1998).

It is within this framework that the importance of the personal and social education of individuals is seen, including a scientific-technological component without which this will not be achieved. Therefore, it is suggested that every individual should have sufficient scientific-technological knowledge to make possible the understanding of some important phenomena in the world and to take democratic decisions in an informed way, from a position of shared social responsibility. This position, although a widely defended and accepted principle today, nevertheless raises problems about the means and extent to which it can be achieved.

Even though formal education represents only one part of each person's access to information and global education, this does not diminish the responsibility he/she has in contributing towards social demands. The question which is put then is that of defining the boundaries of scientific knowledge proper for the school context, in such a way as to contribute towards the individual scientific culture and as a foundation for each person to build on the development of this knowledge.

Early science education in school

The need to promote basic scientific-technological education for all from the first years of school has been a common theme for the vast majority of researchers and educators in the light of the above discussion. It is from this perspective that it is argued that primary schools will always have to create some understanding, even if simplified, of the process and nature of science, as well as the development of a scientific attitude towards problems (Harlen, 1992).

Some educators consider that science is difficult to teach and to learn, as well as that some complex concepts can only be taught at more advanced levels of schooling. Moreover, scientific knowledge is frequently viewed as independent of the context, because it is supposed to be valid for any situation. However, an increasing number of authors argue that science teaching must be organised around situations close to real life, in which pupils can understand the value of their learning and the application of scientific knowledge (Ayala, 1996). Certainly, in the last few years research, Science Education has shown the need to revise the epistemological basis of its teaching, particularly in the early years, in order to facilitate more adequate interconnection between theory, observation and experimentation in classroom practice.

In the first place, this implies the recognition that pupils have ideas or 'informal theories' about many of the areas that formal learning covers and which affect the interpretation of daily phenomena. Teachers should be aware of these ideas, because they can be or can lead to, 'alternative conceptions' which, because they often diverge from acceptable scientific concepts, function as epistemological obstacles to the construction of new knowledge. Such ideas are based on children early experiences and on the interaction provided by adults, whether it be a parent, friend or teacher.

However, through an adequate formal interaction with adults, young children may develop important scientific skills, such as observational and classificatory skills and the ability to raise questions (Johnston, 1996). That interaction may (Johnston & Gray, 1999):

- promote experiences with a specific focus or learning objective;
- function as a role model by observing and expressing ideas themselves;
- create an opportunity for asking questions to challenge thinking or develop the experience further;
- act as motivation for children to express their ideas and look for other extended, similar or new experiences.

Secondly, it is recognised today that young people avoid science, considering it a closed and dogmatic area of knowledge. To combat this position requires adopting contextualised teaching from the beginning, in which the importance of daily life is a fundamental aspect. In this way teaching should, on the one hand, concentrate on relevant personal and social themes and, on the other hand, be flexible enough to adapt when conditions change (Pedretti & Hodson, 1995).

Children acquire scientific, technological and practical knowledge through their everyday experiences, namely in their homes, in the classroom, playing, travelling, shopping, ... Through adequate curricular activities these daily contexts may be used to develop scientific knowledge at school. Although most primary school teachers would agree that children learn in a holistic way, we need to ensure that classroom science activities create opportunities to encourage similar, transferable skills (observing, problem-solving, communicating social and motor skills) and processes of thinking (prediction, speculating, evaluating) (Boorman & Rogers, 2000).

Thirdly, it is now recognised that from a very early age children should be involved in practical activities with clear aims. In effect, children can develop from merely manipulative and sensorial knowledge to the establishment of causal relations and even to an interpretation of those relations through explanatory models (Sá et al, 1996).

This last principle, with its unavoidable relationship with the two former ones, constitutes the basis of the devised primary school activities here presented.

Experimental activity as a suitable methodology for early science education

Experimental activity is nowadays taken to be fundamental in the learning of science by the majority of (if not all) researchers and teachers. Nevertheless, this position, which is more or less generally accepted, does not imply identical understanding amongst those who defend it (Wellington, 1998).

For some of them, the physical involvement, like objects and materials manipulation in the classroom, represents, in itself, a means and/or a type of learning with educational value. A great variety of types of practical work concerning the exploration of methods and techniques (for example, weighing, measuring, using a pipette, filtering, preparing slides for microscope, building electrical circuits...) are based upon this point of view. Those who take this position tend to use diverse means in order to improve manual techniques to increase the rigour of the results obtained. Taking as an example the determination of the mass of an object, concern is focused on finding the answer using different kinds of scales. In the same way, the measurement of the volume of a liquid would be done by using graduated flasks, test-tubes, burettes and pipettes, in order to prove that the physical quantity value depends on the instrument used.

Others, however, defend the learning of methods and techniques as a means of giving answers to questions for which they are fundamental. In this group, there are various understandings concerning the nature of these questions. For some people, the activities are of a markedly academic nature, as the case of the verification of mass conservation in chemical reactions or the determination of the distances bodies moving at different velocities have travelled when they come to rest. Others prefer activities which put in evidence the inadequacy of pupils' alternative conceptions, which is the case with the belief that mass varies during a change of state. Yet others select activities which allow solutions for problem-situations generated in familiar contexts, as is the case in the calculation of the minimal distance that two moving vehicles should maintain between each other so that, if the first one stops, the second can stop without hitting it.

But experimental activity has started to be brought into question for other reasons. For some educators there is no one unique means of experimental work which should be given pride of place. Instead, there is room for diverse forms according to the aims of what is being done. Thus, it is possible to see some value in demonstrations given by the teacher when dealing with such things as the manipulation of dangerous objects and materials (like the reaction of sodium with water). However, this would not be a defensible position in the case of the measurement of the volume of a liquid with a pipette, where pupils' ability could only be developed through direct manipulation.

From the epistemological point of view, experimental work can also be seen through its relationship to the theoretical conceptual domain. Some use it to check laws and principles previously covered, whilst others defend it as a means of reaching them[2]. There are also those who emphasise the need for investigative experimental activities, organised in such a way that the searching of solutions for problems, as well as the formulation of hypotheses and the design of experiments are defined by pupils with the help of the teacher.

We consider this last perspective to be the one which gives most educational value to experimental work, the only one which permits a reply to questions that theory does not resolve alone and which allows pupils to recognise the nature of scientific activity.

The question which now arises is the conception of activities that, based on the logic mentioned above, can be relevant and useful for pupils' learning. This is where the choice of contexts familiar to the pupils is fundamental, assuming that the problem-situations to investigate have a conceptual framework.

This principle, applicable to science education in general, becomes almost obligatory when thinking about the first years of schooling (Johnston, 1996). For children at this age, the idea of familiar contexts must be understood as something in their personal lives, namely concerning relationships with objects, phenomena, places, living things, from their daily lives.

In fact, meaningful contexts are fundamental in stimulating children's involvement in the learning process. Choosing contexts that allow them to think, to do things by themselves, to ask questions, to take control and to make decisions is a relevant way to provide opportunities that enable children to use their own intellectual skills and to extend and develop them to meet new challenges in science learning (Blenkin & Kelly, 1996). To reach these opportunities requires time, space, interaction with children and the design of activities with children and the design of activities built on the experiences they have brought to the situation.

These are the basic ideas which guided the choice and organisation of the activities that are presented in the next section.

Experimental activities using familiar contexts

In the first years of schooling, it is usual and makes sense to explore the concepts which allow the understanding of materials and objects behaviour when in contact with water. Water is an indispensable substance for life, whether for its direct use (food, personal hygiene, cleaning, ...) or for its use in industry, agriculture, in pastimes and leisure, or even as a means of transport. Its multiple functions probably make it one of the substances children know best. Its abundance also leads to the idea that liquids in general contain water (Driver et al, 1994). On the other hand, the term water is used in daily life to designate things which really are aqueous solutions (seawater, tapwater,...). The great number of phenomena associated with the behaviour of materials in water, as is the case with dissolving and floating, justifies children starting with understanding these.

The activities described in this paper were experimented in the classroom with pupils from 6 to 8 years old and tried to develop aspects related to these two concepts[3].

As far as dissolving is concerned (Activity 1), pupils had the opportunity to understand, for example, the importance of the volume of the solvent, the importance of the mass of solute, the importance of mixing, the importance of the state of division of the solute and what kind it is.

In the case of floating (Activity 2), there was room for the exploration of some factors that condition and do not condition the behaviour of objects in contact with water and also with other liquids.

For each of the cases, the teacher chose one of pupils' real-life situations which is common in their day-to-day lives and where the respective concept is important for the understanding of the phenomenon. This situation was played out by the pupils in the classroom as a starting point for the subsequent activities. At this stage there was no instruction given by the teacher, so that pupils behaved as they would normally. From this point on, activities were controlled by the teacher, including the definition of problem-questions, the identification of independent variables, the construction of hypotheses, the planning of experiments to test these, the carrying out of these plans and the answers to the initial questions. These answers led to the formulation of new questions which the initial problem had not yet raised.

Everyday experiences, such as dissolving a sweet and floating potatoes and apples in water, can also help children to experience first-hand, investigative learning and, at the same time, to develop their motor skills, control, hand-eye coordination, holding,... . Moreover, they also provide opportunities for children to develop social skills in cooperation, communicating ideas, taking turns, sharing, helping and working as a group.

Activity 1: Dissolving a sweet

Everyday life context

All children from an early age like to suck sweets and have already noticed that it is possible to take different amounts of time to eat a sweet. The act of sucking a sweet is simultaneously a pleasure for children and a situation in which dissolving takes place. There are, however, some differences between the real situation and the academic context of testing and control of dissolving a solute in a solvent. Although these differences do substantially divide one context from the other, the didactic exploration of the real one allows the understanding of the phenomenon of dissolving a solid in a liquid.

Classroom context

- Teacher gave each of the pupils a sweet and asked them to suck it, without other instructions.
- Teacher observed pupils discreetly. When he/she saw that some of them had already eaten the sweet started a series of questions:

  "Who has already finished the sweet?"
  "Who still has some left?"
  "Why have some of you already finished and others not?

These questions intended that pupils focus on this fact in order to find an explanation for it. This is where structured activities began and followed a scientific methodology.

- Teacher began by listening to the answers pupils gave to the questions asked. Here are some examples:

"I ate the whole sweet because I sucked it quickly"
"I ate it all because I bit it"
"I ate it all because I moved it around in my mouth a lot"
"I still have a little because I didn't move it around much"
"I still haven't finished it because I only sucked it a few times"

Each of the answers allowed the teacher to use it to explore the factors that affect the dissolving of a sweet in water.

Questions for investigation

- Teacher systematised the reasons that pupils presented as justifications for having finished or not having finished eating the sweet.
- Terms used by pupils were discussed and then transformed into the respective terms used in scientific language:

"bit" - divided into smaller pieces/ crushed, ground down;
"moved around" – mixed;
"sucked" - added solvent.

From this point on pupils were able, with the help of the teacher, of identifying factors which influence the time it takes to dissolve a sweet in water:

- the size of the sweet;
- the type of sweet;
- the state of division of the sweet;
- the volume of water;
- the movement of the system sweet-water.

Each of the factors corresponds to an independent variable whose effect on the dependent variable (time to dissolve) can only be evaluated by controlling the other variables.

Each factor allowed the formulation of a specific question (by the teacher) and of hypothesis to explain it (by the pupils), which basically come from the everyday life context previously explored. Some examples of these questions are:

Question 1: Does a smaller or a larger sweet dissolve more quickly (in less time)?
Question 2: Do all the sweets take the same time to dissolve?
Question 3: Does a whole sweet take the same time to dissolve as a crushed sweet?
Question 4: Does the amount of water the sweet is put into affect the time it takes to dissolve?
Question 5: When you move a sweet around in water does it take more or less time to dissolve?

Experiments

Each question deals with the study of a different independent variable in the process of dissolving. Because of this, it is essential that children recognise that the answer to each of these questions will only be valid if the experiment is conducted keeping the other variables constant. The role of the teacher is to ensure the pupils' planning of the right experiment for each question, particularly the independent variables chosen and the dependent variables to be measured.

The control of variables demands the experiment to be carried out in a laboratory setting in which it is possible to evaluate:

- the time taken to dissolve (using a clock or a chronometer);
- the mass of solute (using weight scales);
- the division state of the solute (using a mortar);
- the volume of solvent (using graduate cylinders or flasks);
- the motion of the solute-solvent system (using a stirring rod).

Based on these principles, an experiment was designed for each of the questions (with the help of teacher) and carried out by pupils. The collected data were recorded by each group and, interpreted and discussed in the class.

For each experiment, the planning board model filled in by children was that put forward by Goldsworthy and Feasey (1997), which involves the following steps:

- what we are going to change (independent variable being studied)?
- what we are going to measure (dependent variable chosen)?
- what we are going to keep the same (independent constant variables)?
- how we are going to record the data (list, table, graph, ...)?
- what equipment is needed (sweets, flasks, water, cylinders, scales, clock, mortar, rod, ...)?
- what we think will happen (preview of results)?

In Table 1, the application of this model to the five questions is presented. After each of the five experiments has been carried out, pupils were invited:

- to record data (the time to dissolve completely each sample) in the second column;
- to compare the recorded data with they thought it would happen;
- to produce answers to the questions they started with (which led to the experiments);
- to give new predictions for the new questions arising from the experiments.

Children learning outcomes

The teacher and children carried out experiments which allowed pupils to test that:

- The larger the mass of solute (the sweet) the longer the time needed for it to dissolve completely (Question 1).
- Different kinds of solutes (sweets) take the same time to dissolve or not (Question 2).
- The greater the division of the solute (sweet) the less time it takes to dissolve completely (Question 3).
- The greater the volume of solvent (water) the less time it takes to dissolve completely (Question 4).
- The more agitated the system the less time it takes to dissolve completely (Question 5).

These results should be considered valid within the limits used in the experimentation (a certain solute; a certain solvent; a solute-solvent relationship within the limits of solubility of this solute in this solvent at room temperature). For this reason, it is important that the teacher has previously tried the required amount of solvent.

After the teacher has made sure of pupils' understanding about the meaning of these results (still in a cause-effect relationship), they were involved in the construction of new predictions through answering questions put by the teacher, for example:

TABLE 1

Experiment Designed for:	What we change	What we measure	What we keep the same	What we record	What we need to have	What we think will happen (examples)
Q1. The influence of the mass of sweet on time to dissolve	Mass: whole sweet, half sweet, quarter of a sweet (a)	The time to dissolve completely each sample	Type of sweet, state of division, volume of water & agitation of system (b)	1st column: size of the 3 samples (c)	3 samples, 3 graduate flasks, water, 3 rods, clock or chronometer	*"the biggest sweet will take most time because it is bigger"* .....
Q2. The influence of the type of sweet on time to dissolve	Kind (type): 3 different sweets of approx. the same size (d)	"	Mass of sweet, state of division, volume of water, agitation of the system (b)	1st column: kind (type) of the 3 samples (c)	Equipment as above	*"the harder sweets take longer to dissolve"* .....
Q3. The influence of the division state of sweet on time to dissolve	State of division: 1 whole sweet, 1 divided into 3 or 4 pieces & another crushed (e)	"	Type of sweet, mass, volume of water & agitation of the system (b)	1st column: state of division of each sample (c)	Equipment as above (+mortar)	*"the sweet that is broken up most dissolves first"* .....
Q4. The influence of the volume of water on time to dissolve	Volume of water: 3 different quantities of water in the proportions 1:2:4 (f)	"	Type of sweet, mass, state of division & agitation of the system (b)	1st column: volume of water used in each test (c)	Equipment as above (+ measuring cylinder)	*"the one with most water will dissolve first"* .....
Q5. The influence of the agitation of the system on time to dissolve	Stirring: 1 system no stirring, 1 stirred occasionally & 1 stirred continuously (g)	"	Type of sweet, mass, state of division & volume of the water (b)	1st column: state of agitation of the system (c)	Equipment as above	*"when you stir it more, it dissolves more quickly"* .....

(a) Children should understand that they are dealing with three different quantities of the same material.
(b) - Type of sweet refers to brand, colour, flavour, ... - State of division refers to the number of pieces of each sample.
- Agitation of the system refers to the option taken whether to cause movement (or not) of the solute and the solvent (it could be a lot, little or none).
(c) The data can be organised into a table with two columns, in which the 2nd refers to the time necessary for the sample to completely dissolve. It can only be filled in after the experiment. The 1st column refers to planning so it should be filled in prior to the experiment.
(d) Children should understand that only the kind of material is different (for example, colour, brand, ...)
(e) Children should start with 3 sweets which are whole and the same, dividing two of them in different parts using a mortar.
(f) Children will have to use sweet samples that are the same in terms of type and division state.
(g) Children will use sweet samples that are the same in terms of type and division state, the difference being in what they do after the addition of solvent (stirring all the time, sometimes or never).

"How could we reduce the time necessary to dissolve a sweet by half?"
Some pupils' answers were:
- *"stirring a lot... "*
- *"crushing ..."*
- *"using more water ..."*

Moreover, pupils' were also able to predict the results coming from the conjugation of two or more of these factors.

Activity 2: Floating potatoes and apples in water

Everyday life context

The preparation of food at home is familiar to children from very early on and, because of this, can provide a favourable context through which to observe the behaviour of objects. For example, all children will already have seen that when potatoes are placed in water they sink and that carrots, turnips and apples float.

Classroom context

- In a deep container with a lot of water, teacher placed an apple and a potato (bigger than apple) and asked pupils to observe.
- Teacher asked why the apple floats and the potato sinks.
- Answers from the pupils were:

"the potato is heavier than the apple"
"the potato is bigger than the apple".

These replies allowed teacher to question pupils about the reasons these objects float/ do not float in water.

Questions for investigation

- With the help of the teacher, pupils listed the factors that they believed influence floating:

- the mass of the object;
- the size of the object;
- the height of the liquid in the container.

- For each of these factors (independent variables put forward by the pupils) a specific question was formulated by the teacher:

Question 1: Does the potato sink because it is heavier than the apple? (this is the same as: does the apple float because it is lighter than the potato?)
Question 2: Do big and small potatoes always sink? (this is the same as : do large and small apples always float?)
Question 3: Does the height of the water in the container affect whether the apples/ potatoes float/sink?

Experiments

These questions were answered by the pupils in a way that is scientifically unacceptable. For instance, the answer to questions 1 and 3 was frequently affirmative and negative for the question 2. So, the finding of an adequate answer requires a fair-test experiment which could prove to pupils the legitimacy or not of their predictions.

As in Activity 1, the experimentation followed the scientific model fair-testing. In all of the questions, the dependent variable is the behaviour of an object in water (floating/sinking); the independent variables to be tested are the mass (Question 1), the size (Question 2) and the depth of the liquid (Question 3).

In Table 2, the summary of the experiments is shown.

TABLE 2

Experiment designed for	What we test	What we predict
Q1. The influence of the mass of the object on flotation	The behaviour of an apple & 3 potatoes (bigger, the same mass, & smaller than the apple) in water	*"the apple will float'* *"the biggest potato will sink"* *"potatoes of the same size & smaller than the apple will float"*
Q2. The influence of the size of the object on flotation	The behaviour of potatoes in water (whole, halves, in small pieces)	*"the whole potato will sink"* *"the half a potato might float/not float"* *"the pieces of potato will float"*
Q3. The influence of the depth of the water on flotation	The behaviour of a potato (or piece of potato) in water in 3 containers of clearly distinguishable different depths	*"in the deepest container, the potato will float"* *"in the other containers, the potatoes will sink"*

Children learning outcomes

The carried out experiments allowed pupils to test that:

- Whatever the mass of the potato, it will never float in water (Question 1).
- Whatever the size/state of division of the potato, it will never float in water (Question 2).
- Whatever the height of the water or the depth of the container, the potato will never float in water (Question 3).

Pupils could therefore verify that floatation does not depend on the mass or size of the object (potato), nor the quantity or height of water used.

When faced with the teacher question *"What does the floatation of an object depend on?"*, pupils frequently tended to reply that it depends on its nature (*"it floats because it is apple"; "it sinks because it is potato"*).

It is not an easy task to explain the phenomenon to young children. It could nevertheless be shown that the behaviour of an object also depends on the kind of liquid it is placed in. Taking up the case of the potato once again, it is sufficient to place different sizes of potatoes in very salty water to be able to see that they all float.

It is through these different behaviours of potatoes in liquids (water and salty water) that pupils begin to understand the phenomenon of floatation. At this point, they prove that floatation always depends on the system object-liquid and that the explanation cannot be based on looking at only one of these two parts.

Conclusions

The written and oral reports presented by the teachers involved in the activities allowed us to draw important conclusions about the desirable innovation in the teaching and learning of primary science.

1. The joint development (by researchers/trainers and teachers) of activities to be carried out with pupils in the classroom seems to be an enriching methodology for teachers education, because it improves:

- the scientific knowledge of each teacher, as well as his/her desirable skills and attitudes in and about science;
- the awareness of teacher's own scientific-didactic difficulties;
- the teacher's confidence required to face new situations.

2. The activities reinforced the idea (not always accepted) that even very young children may learn concepts and scientific procedures which are traditionally reserved for older pupils.
3. The choice of contexts familiar to pupils, as a starting point for the formulation of problems concerning curriculum subjects, seems a promising, useful and motivating way to promote the learning of concepts with which they are associated.
4. The use of everyday contexts opposes the idea that young pupils don't like to learn science.
5. The adopted experimental methodology seems to be useful to favour the conceptual change of pupils' previous ideas in the domain under study. It also allows the development of important features of the early scientific learning process, such as observational and classificatory skills, the ability to raise and answer questions, the setting up of interrelationship between different features, and the development of important scientific attitudes (curiosity, perseverance, respect for evidence, self confidence and open-minded).
6. The scientific approach to learning endorsed by this methodology offers (amongst other things) a safe stimulating environment for children to learn through exploration and experiments.

In short, this scientific methodology affirms, reinforces and develops young children's emerging skills, which constitutes a desirable outcome of primary school science.

NOTES

[1] Study carried out with financial support of Portuguese Science and Technology Foundation/ PRAXIS XXI-Ministry of Science and Technology.

[2] Discovery learning comes in the latter empirical position which, despite being around for 30 years, is still frequently used.

[3] The activities were developed in 1998 through workshop training sessions which lasted eight hours each on an in-service for primary school teachers training course (three groups of 30 teachers per group).
Teachers taught in a total of 19 official Portuguese primary schools from different regions and social settings.
The discussion in each group and with the 3 researchers/trainers allowed each teacher to:

- recognise their own ideas and conceptual difficulties;
- compare different views on the usefulness and conduct of experimental activity;
- foresee possible difficulties for the pupils with the themes under focus;
- construct record sheets to use in the classroom;
- differentiate levels of ability in experimental activity in accordance with the school year of the pupils;
- deepen their scientific knowledge in the areas of the course.

In this training course no rigid rules about the carrying out of activities in the classroom were set out. Nevertheless, each teacher was required to produce a final report of the work done, including pupil records.
The evaluation of these records, whether in individual files or on posters produced together with each class, provided a collection of data which supported the suitability of the didactic proposals presented.

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