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# About the editors and the SMILE Group

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SCIENCE AS A
MOTIVATING AND
INVIGORATING
LEARNING
EXPERIENCE

**SMILE** is composed of a group of committed science teachers and educators who are interested in developing and implementing science curriculum materials to make school Science a Motivating and Invigorating Learning Experience for all students. SMILE recognizes the multi-dimensional nature of learning outcomes in science and is committed to explore innovative ways of assessment as a key component of curriculum development. Another aim of this Group is to carry out action research on teacher development associated with school-based curriculum development.

**SMILE** invites science teachers and teacher educators interested in sharing the SMILE vision to join the SMILE family. To join SMILE, you may get in touch with any of the editors or complete the following form and send to: SMILE Group, Department of Curriculum Studies, University of Hong Kong, Pokfulam Rd., Hong Kong, or fax: 28585649.

## Application to join SMILE

Name: ____________________ Tel.: __________ Fax: __________

Institution: ______________________________________

Address: ______________________________________

Aspect of SMILE that interests you: ______________________________

______________________________________

# Preface

The work that has led to the project SMILE and this publication arose out of a belief. A belief that science can be interesting and accessible to all students. Teaching science in the '90s is more challenging than ever before because the society has changed, the students have changed, and access to school education is now the right of all children instead of just a selected elite, while the school science curriculum and the teaching approach has not seen much change. The belief was that if we revamp the curriculum structure and the approach used in teaching science, all students, the gifted and the low academic achievers alike will find science much more exciting and accessible. Core to this was the belief that the science curriculum should be built around issues and technologies that are close and relevant to our everyday life. The attempts of science to explore the more fundamental aspects of nature and the creation of theoretical models and laws as the fruits of such explorations are less accessible to students or to the general public, and should best be done through the artful interwining of such introduction with the teaching of more relevant technologies and issues. It is thus not surprising that science as it is taught in schools through a top-down approach starting from laws and principles is often found to be alienating. Another belief was that the learning activities must capitalize on the existing knowledge and skills of students in order to foster motivation and self-confidence.

The vision of a new curriculum approach to science started to come to life when I was granted a CRCG grant from the University of Hong Kong to develop, implement and evaluate such a curriculum belief in a few schools that has a predominant intake of low achievers. The rationale for piloting with academic low achievers was not only that I wanted to look for a science curriculum approach that would be appropriate for this group of students. More importantly, if this approach can motivate academic low achievers and if they can demonstrate reasonable learning outcomes under such an approach, one would then have much more confidence that it would work with a much wider student ability range.

Another belief for this project is that for any curriculum development to be successful and to take root, school-based development with strong teacher participation mandatory. Thanks to the commitment and support of the schools and teachers involved in the project, a school-based curriculum development project involving two schools was piloted at secondary one level for integrated science. This phase of the project was completed as planned at the end of the academic year '94-'95.

The interest that the school-based project has subsequently generated have encouraged us to go for further developments. One outcome is the decision to form a **SMILE** group. SMILE stands for **Science as a Motivating and Invigorating Learning Experience**. This group now seeks to recruit more interested science teachers and continue to pursue further science curriculum innovations in more schools. Another aim of this group is to carry out action research with teachers on assessment of learning outcomes as well as on teacher development associated with school-based curriculum development. SMILE believes that a reduction in curriculum content or curriculum demand will not relief fundamentally the challenges faced by science teachers in the '90s and beyond and hopes to contribute to the proactive search for ways of making science interesting and accessible for all. The publication of this volume is the first major project since the formation of this group. We hope that through this publication, we can share with the wider community of science teachers and teacher educators our ideas and experiences.

For a long time, Hong Kong has imported its science curricula in block from U.K.. It is our hope that more and more of our science curriculum can evolve from local school-based developments. This is the only way that school science can become relevant and accessible to all students in Hong Kong. We do hope that science teachers and teacher educators interested in sharing the SMILE vision will get in touch with us, join the SMILE family and thereby to extend and strengthen the work that it can do.

Nancy Law
Department of Curriculum Studies
University of Hong Kong

May, 1996.

# INTRODUCING SMILE

Nancy Law

SMILE stands for **Science as a Motivating and Invigorating Learning Experience**. The purpose of the SMILE project is to make school science a motivating and invigorating learning experience for students.

Students getting into the Science laboratory for the first time at the beginning of their first secondary school year are normally very excited, fascinated by the many exotic apparatus and dreams of performing interesting experiments by themselves. This excitement normally lasts for a few months and then reality sinks in. Students might still enjoy the activities in the laboratory, but Science seems to take on a very different composition now that they have come much closer to it. It consists of a lot of difficult and abstract terms bearing little relevance to daily life. The connection from one activity to another and the purpose of each activity is often not clear.

***Students getting into the Science laboratory for the first time are normally very excited, fascinated by the many exotic apparatus and dreams of performing interesting experiments by themselves.***

Can school science be realistically taught in a motivating and invigorating manner to the average student or even low achievers so that students can achieve the intended curriculum goals while enjoying the subject? The answer is YES, a conditional yes.

**Why is school science difficult?**

In order to make school science a SMILE experience, it is necessary to reflect on why school science is generally not so. There are two main reasons why school science is difficult. One is the way the curriculum is structured. The other is the role of the learner implicit in the curriculum approach.

### *A top-down, theory-led, non-intuitive curriculum*

Our school science curriculum is organized very much in a top-down manner according to the rationalized structure of knowledge in the scientific disciplines: beginning with abstract concepts, definitions and principles, followed by elaborations and illustrations, finishing with applications. It thus looks well structured and logically ordered to science teachers who are well educated students of science. It presents a picture of science that bears little resemblance to the popular image of science as involved with exciting new inventions, providing solutions to problems and closely related to technological advances. School science presents itself as cool, objective knowledge with a few abstract, universal truths at its pinnacle, formed by a host of abstract concepts and terms. Such concepts are oftentimes either entirely unfamiliar or counter-intuitive to our everyday commonsense understanding. School science bears little relevance to our everyday life and does not seem to involve itself with much of the issues, social or otherwise that we face everyday, except for some brief mention of major topics such as environmental conservation.

***School presents a picture of science that bears little resemblance to the popular image of science as involved with exciting new inventions, providing solutions to problems and closely related to technological advances.***

### *Unachievable inductivist "discoveries"*

The current science curriculum puts a lot of emphasis on experimental work, which some may interpret as encouraging a "discovery" approach. However, the assumption that science is "objectively derivable" from observation is an extremely harmful one. Often, students are expected to make huge leaps from observation to conclusion. For example, the secondary 1 syllabus recommends that after observing coloured crystals dissolving in water and the reduction in colour intensity as the solution is diluted, "Pupils should be able to infer that matter is made up of tiny particles."

***The assumption that science is "objectively derivable" from observation is an extremely harmful one.***

Pure induction can only work in the case of formulating "experimental" (empirical) laws that describe relationships between entities. Major scientific principles such as the particulate model of matter lie in the realm of "theoretical" laws which are in fact conjectures and not logically derivable from observation. Such a curriculum not only promotes a wrong conception of science, it may also lead to a sense of perplexity and failure in students when they find that they cannot "naturally" arrive at the expected conclusion supposed to be so obvious.

***Major scientific principles lie in the realm of "theoretical" laws which are in fact conjectures and not logically derivable from observation.***

***Decontextualized, isolated teaching of requisite skills and knowledge***

Another feature often found in the science curriculum is the rigid assumption that individual requisite skills and knowledge must be taught before the teaching of complex materials. For example, the teaching of isolated process skills like "careful observations" and measuring temperatures independent of specific contexts or purposes often makes the learning experience meaningless and trivial. A motivating curriculum should pose the right challenge to students so that they can be actively involved in the learning tasks, thinking and contributing during the process.

***A motivating curriculum should pose the right challenge to students so that they can be actively involved in the learning tasks, thinking and contributing during the process.***

***A curriculum model that forces the learner to be a blank slate and passive***

As the school science curriculum begins with and focuses on unfamiliar concepts and alien ideas, instead of familiar, intrinsically interesting phenomena or themes, the learner is automatically placed in a position where s/he seems to have no relevant prior knowledge. S/he is at a helpless, disadvantaged position with no clue of her/his own on how to proceed except to wait for instructions and guidance from the teacher. This necessitates a passive role and attitude on the part of the learner.

***The learner is placed in a position where s/he seems to have no relevant prior knowledge, helpless and with no clue on how to proceed without help from the teacher.***

## SMILE curriculum - scaffolding from everyday problems and technologies

The SMILE project believes that in order for the science curriculum to be motivating, it must be starting from and structured around everyday problems and technologies that students care about. This is not the same as using "applications" and phenomena as "sets" to start a topic, and dropping very quickly back to the "real agenda". The chosen problem, phenomenon or technology remains at centre stage throughout a teaching unit, acting as a kind of focus or theme. Students will engage in problem solving activities and explorations that they themselves find meaningful. At the same time, the unit needs to be skilfully structured so that students will be led to appreciate that in order to solve some everyday problems, one might need to think of common phenomena in uncommon ways, and that abstract ideas and concepts in science might prove to be profitable ways of thinking.

***The SMILE curriculum starts from and structures around everyday problems and technologies that students care about.***

***Students will appreciate that in order to solve some everyday problems, one might need to think of common phenomena in uncommon ways, using abstract ideas and concepts.***

SMILE sees curriculum development as a process of skilful scaffolding. It starts with problems or technologies that students care about, challenging them to propose designs and solutions that are just beyond their level of existing competence. A right level of difficulty will be a crucial element in maintaining student interest so that students will be able to consolidate existing skills and knowledge as well as learning new ones in context. The scaffolding will guide students from familiar, concrete problems and phenomena to unfamiliar, abstract concepts and ideas in a captivating and challenging journey.

***The curriculum scaffolding will guide students from familiar, concrete problems and phenomena to unfamiliar, abstract concepts and ideas in a captivating and challenging journey.***

**SMILE approach - where learners' experience, knowledge and questions count**

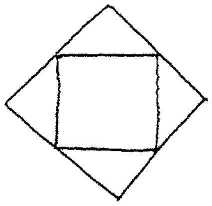
Students do not come to the science classroom as a blank slate. Their life experience and past learning can and should contribute to the learning process in the science classroom. Furthermore, the science classroom should not be concerned only with questions and problems set by the curriculum or the teacher. Students should be able to pose their own questions and volunteer answers. Going through the shortest route of "correct" scientific views and "right" ways of conducting experiments is often not the best way to learn. They only provide sterilized, highly simplified, pre-digested "food" that does not nourish the mind sufficiently for it to mature intellectually. One needs the opportunity to test one's own understanding through formulating ideas and solutions and putting them to work. Mistakes made under such circumstances often constitute a rich source of worthwhile experience more nourishing than any "good teaching" can provide. The SMILE approach thus treasures students' contributions and ideas even when they are incorrect or different from the accepted views and aims at providing ample opportunities for students to bring forward, try out and modify ideas and suggestions throughout the learning process.

***Going through the shortest route of "correct" scientific views and "right" ways of conducting experiments is often not the best way to learn.***

***Mistakes often constitute a rich source of worthwhile experience more nourishing than any "good teaching" can provide.***

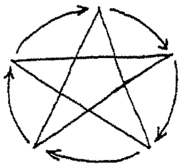
# Experiencing SMILE through WATER & MATTER

Nancy Law



It took humanity more than 2000 years to arrive at a view of matter as we know it:

A model of matter being made up of ATOMS, that all matter is made up of a hundred or so different elements and that the most helpful way to organize them is in the form of a periodic table.

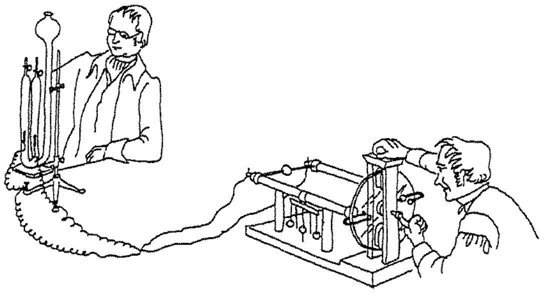


This modern view of matter took shape only within the last 200 years of human history.

However, the mystery of the structure of matter has continued to tease and excite inquisitive minds since ancient history, in China and the West.

Modern science shares the same wish as our ancestors in trying to create a picture, a way of seeing the world, that would help us to make sense of our myriad experiences and to anticipate events and behaviour of the material world around us.

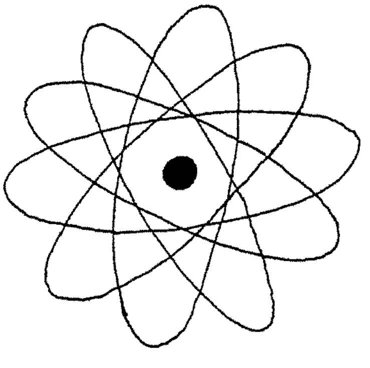
At the time of the Greeks, people believed that the key to good, reliable knowledge was a clear, logical mind. It wasn't until the Renaissance period that people with competing theories seek validation from empirical data.



Since then, the development and refinement of experimental equipment and measuring instruments helped to expose facets of the physical and biological world that were not known before.

Furthermore, such development led to an accumulation of knowledge in the form of empirical laws and generalizations that form a much richer background rubric for scientific creative theorizing.

The birth of modern scientific methods and its quest for objective verification does not change the fundamental nature of all key scientific theories: they are models created by the human mind to interpret and predict what happens in the world around us.

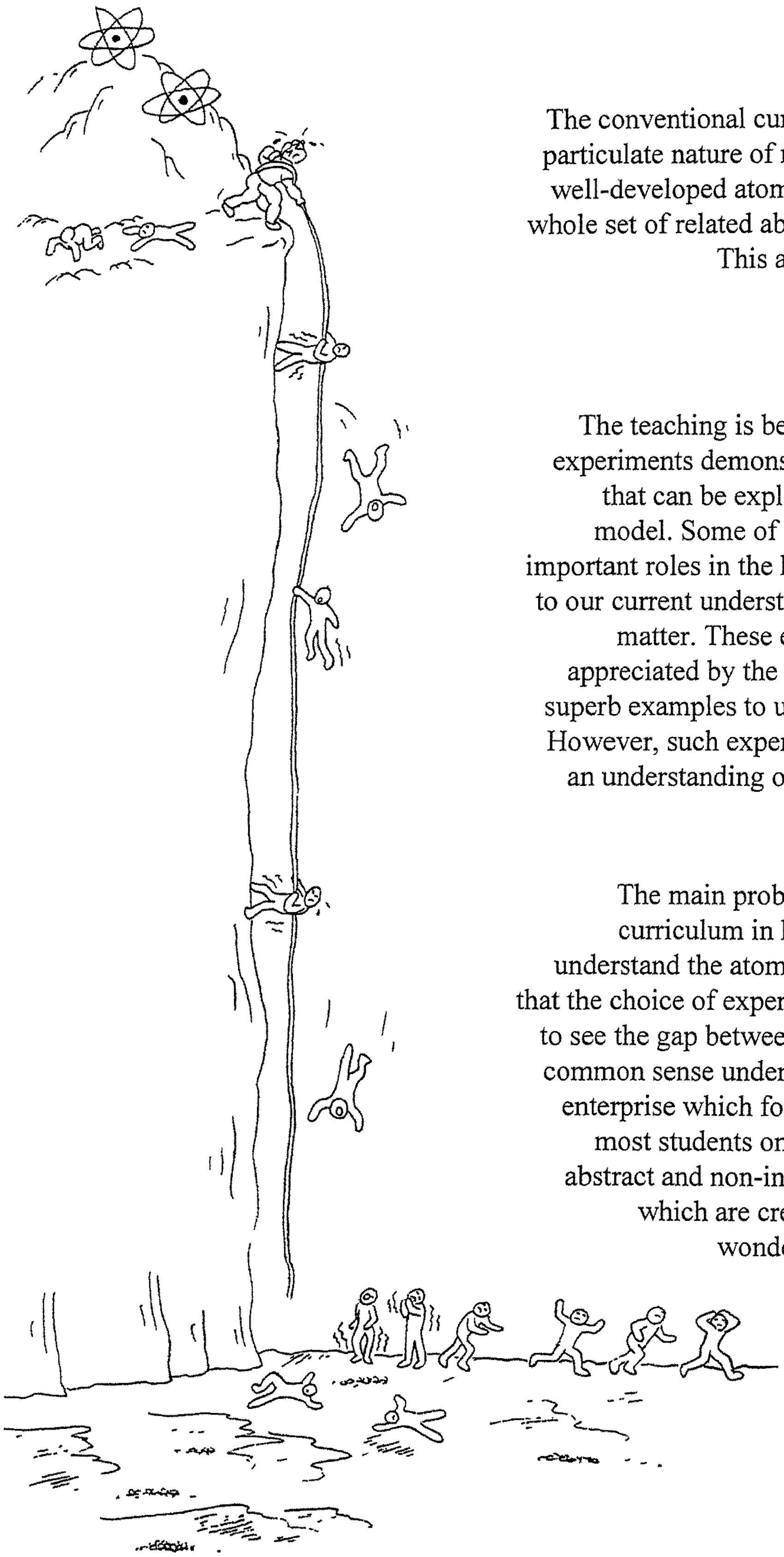


During the long history of man's efforts to make sense of the structure and composition of matter, different models came into fashion and later replaced by others. What is unchanging throughout, however, is a strong sense of wonder and curiosity exhibited by those who worked so hard on building and testing these models.

Can we instill the same sense of wonder in our students?

Is it possible for them to share some of the excitement of hypothesizing about and peeking into the mysterious microscopic world?

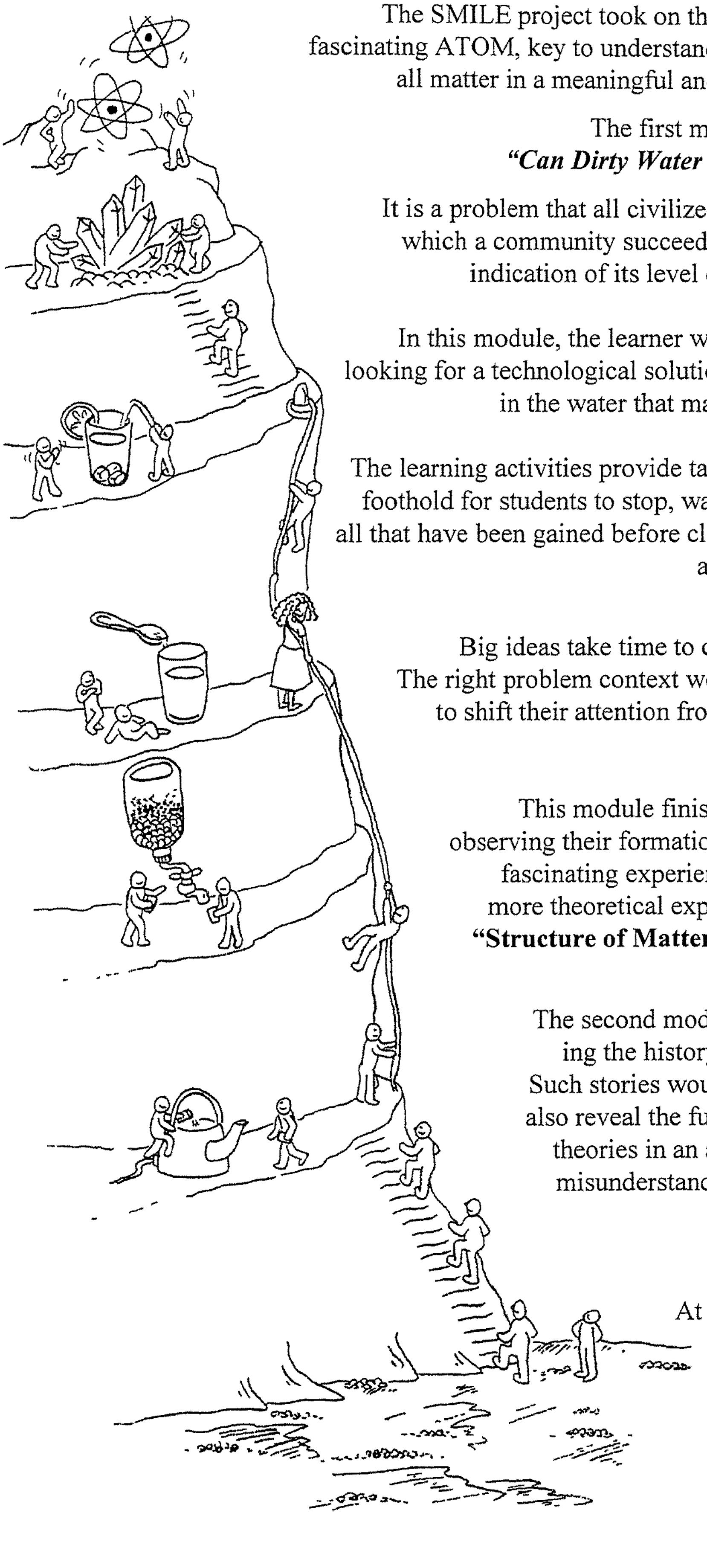
Or, can we at least help them to see that thinking at that level makes sense, is accessible and important?



The conventional curriculum teaches about the particulate nature of matter by starting with the well-developed atomic theory complete with a whole set of related abstract concepts and terms. This approach makes the theory rather inaccessible.

The teaching is being “supported” by some experiments demonstrating features of matter that can be explained using the particular model. Some of these experiments played important roles in the history of science leading to our current understanding of the structure of matter. These experiments are thus well appreciated by the scientifically educated as superb examples to use for teaching purposes. However, such experiments often fail to instil an understanding of matter as was intended.

The main problem faced by this current curriculum in helping students to really understand the atomic theory of matter is not that the choice of experiments was poor. It fails to see the gap between everyday concerns and common sense understanding of the scientific enterprise which forms the starting point for most students on one side, and the highly abstract and non-intuitive scientific theories which are creations of inquisitive and wondering minds on the other.



The SMILE project took on the challenge of introducing the fascinating ATOM, key to understanding the microscopic world of all matter in a meaningful and accessible way in two steps:

The first module starts with the problem
***"Can Dirty Water become a Delicious Drink?"***

It is a problem that all civilized societies face. The degree to which a community succeeds in solving this problem is an indication of its level of technological development.

In this module, the learner will be guided along the path of looking for a technological solution to think about what may be in the water that makes it unsuitable for drinking.

The learning activities provide tangible steps and easier, firmer foothold for students to stop, wander around and take stock of all that have been gained before climbing further toward the less accessible theoretical pinnacle.

Big ideas take time to cultivate even in bright minds. The right problem context would help to orientate students to shift their attention from macroscopic phenomena to microscopic interpretations.

This module finishes with growing crystals and observing their formation under the microscope. Such fascinating experience hopefully would make the more theoretical explorations into the microscopic **"Structure of Matter"**, theme for the next module, more accessible.

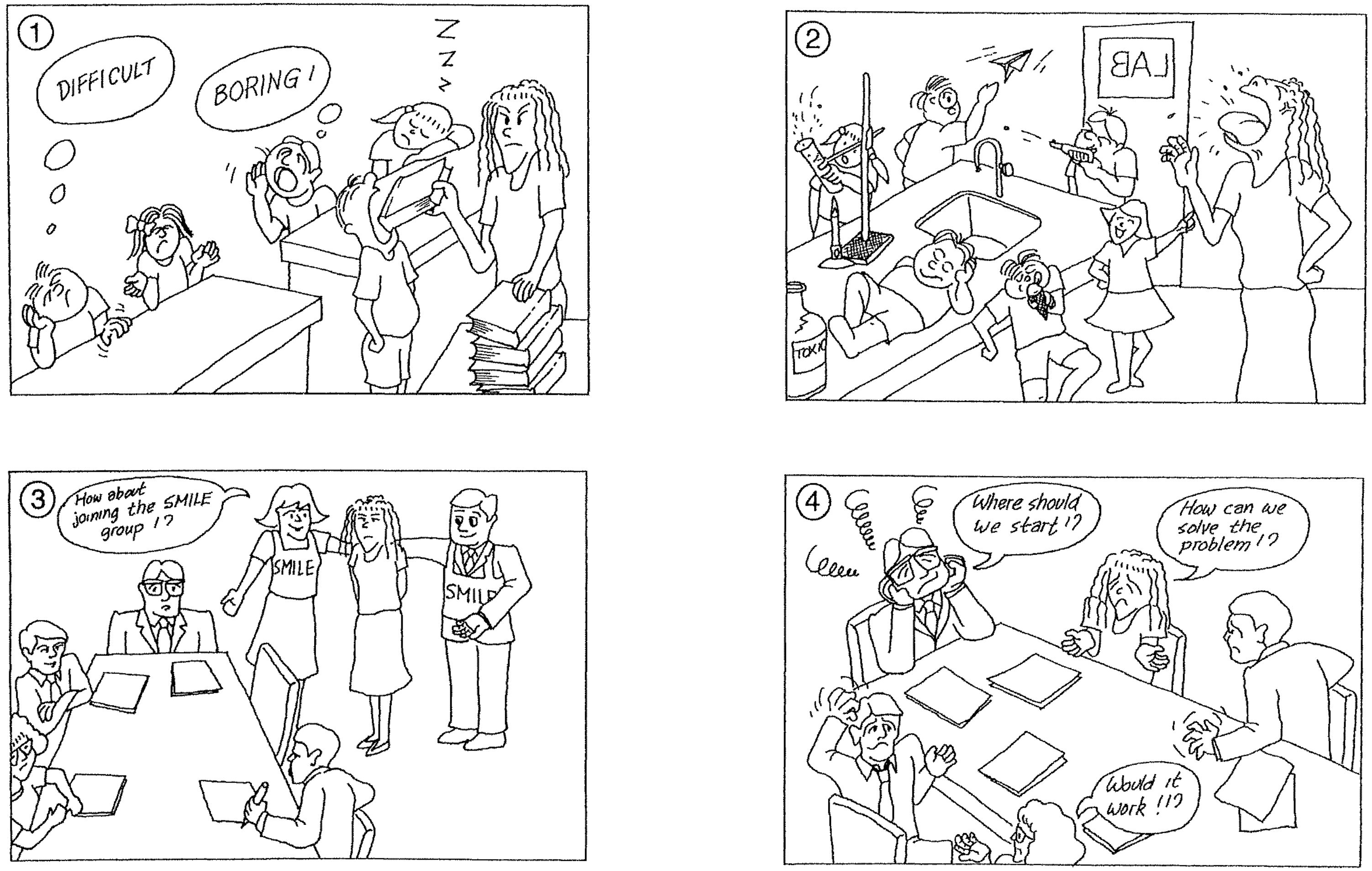
The second module would start with introducing the history of man's ideas about matter. Such stories would not only be interesting, but also reveal the fundamental nature of scientific theories in an accessible way, dispelling any misunderstanding that one should be able to deduce atomic theory directly from empirical observations.

At the end, some students might still find the atomic theory of matter intangible, but the curriculum should have already offered them a lot by way of accessible knowledge and skills in science.

# Teachers' Experiences With SMILE

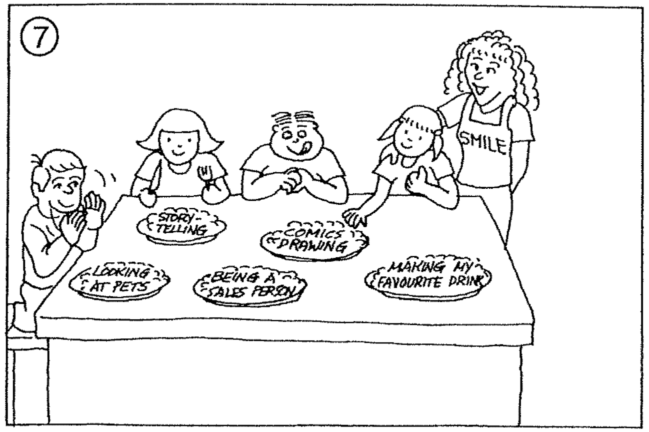
translated by M.L. Lo & B.H.W. Yung

# The SMILE Story

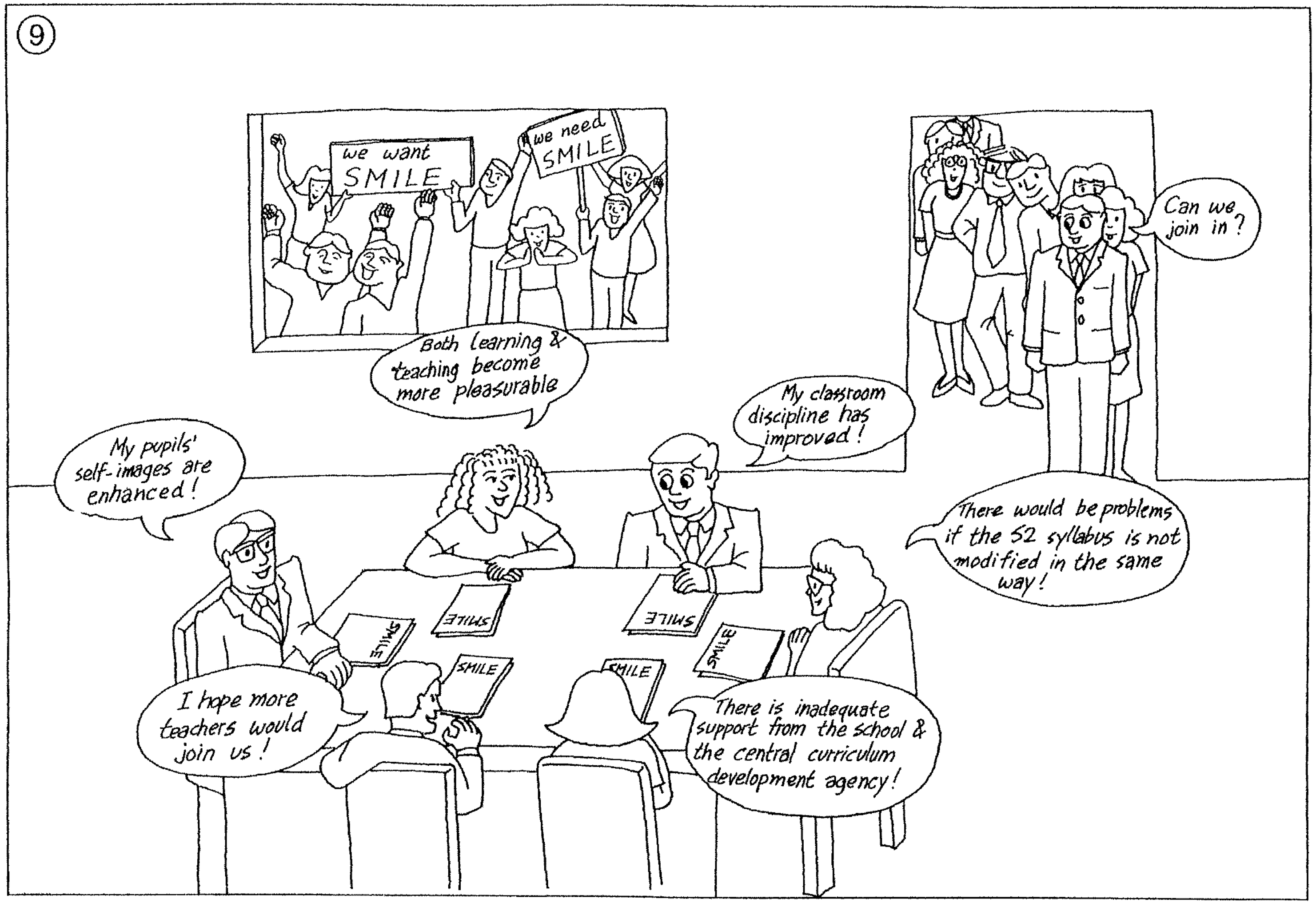


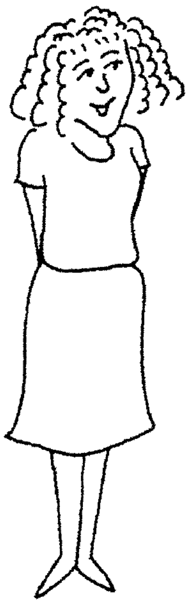
# The SMILE Story






# The SMILE Story






## Those Memorable Days!

*Pong Shui Chi*
*Ho Ngai Prevocational School*
(Translated version)

It was a year ago that I joined the pilot project (phase 1 of SMILE ) initiated by HKU, the memory is still vivid.

*"... experience told me that in any curriculum innovation, what you gain is usually very little compared with what you give, is it worth the effort?"*

I remember the day when I was told by our principal that he wished me to join this project. I accepted with mixed feelings after contemplating for a short while. The Intergrated Science curriculum has been in place for 10 years, it surely is time for a change. Some experiments are really dull and boring, it would be fun to incorporate experiments that are related to our daily lives. However, experience told me that in any curriculum innovation, what you gain is usually very little compared with what you give, is it worth the effort?

*"The most painful moments were those when we had sat for hours, wrecking our brains and yet the long awaited brain wave never came ..."*

Once work had been formally started, it was one followed by another of long and 'terrifying' meetings. During these meetings, we had to design experiments that were related to our daily lives and interesting to students. This was more easily said then done. The most painful moments were those when we had sat for hours, wrecking our brains and yet the long awaited brain wave never came and we did not have any bright idea. There were times I really regretted having joined this project. If it were not for the adequate support from the lecturers of the University of Hong Kong, in the form of both resources and ideas, I think I probably would have quitted long ago.

***"When the painful days were over, the fruits of labour were satisfying and sweet."***

When the painful days were over, the fruits of labour were satisfying and sweet. At the personal level, I have the chance to get in touch with new ideas, new teaching strategies and creative experiments during meetings, and apart from feeling greatly enlightened, I am now more motivated to think about new teaching strategies and activities for my students, and more able to make use of the valuable experiences of other teachers. These surely cannot be achieved by working within the confines of one's own individual classrooms. As for the students, their marked improvements were beyond my initial expectations. The new learning activities were so much more interesting that students became much more involved and motivated to participate in the learning activities. These created a learning atmosphere I greatly enjoyed. Once, I asked a group of excited students who were caressing some small pets they brought to school, "Is this activity interesting?" Their response was overwhelming. One said proudly, "Very interesting. Some of my friends in other schools actually envy me for doing such interesting science experiments!" There are no words which can describe my feeling of excitement and satisfaction at that particular moment.

***"There are no words which can describe my feeling of excitement and satisfaction at that particular moment."***

***"Up till now, I still cherish the memory of those days ..."***

Up till now, I still cherish the memory of those days, the hardship, the struggle, the initial feeling of defeat, and the joy and satisfaction at the end.

# Reflections of a Science Panel Chair on the SMILE Experience

*Choi Cheuk Yin* *Ho Dao College*
(Translated version)

***"...(SMILE). The acronym captures much of the spirits of the project - learning science with joy and purposes."***

I am delighted to hear that the 'Integrated Science Project' initiated by the Department of Curriculum Studies, The University of Hong Kong (HKU) has now evolved and developed into a systematic school based curriculum project entitled 'Science as a Motivating and Invigorating Learning Experience' (SMILE). The acronym captures much of the spirits of the project - learning science with joy and purposes.

As one of the teachers participating in the first phase of the project, I am glad to see that the project has now identified for itself a more well-defined set of aims and with more enriched contents. I strongly believe that science curricula in Hong Kong should be moving in this direction. That is, more related to daily life and technology so that students would be interested and motivated to learn how to solve problems.

***"At the very beginning of the project, colleagues in our school did not have much confidence."***

At the very beginning of the project, colleagues in our school did not have much confidence. We had two major concerns. Firstly, it was our inexperience in curriculum development: Though we had identified the broad aims, we did not know which topic was the most appropriate to begin with. Most of us were accustomed to teaching by following the textbook closely, supplemented only occasionally by extra materials from elsewhere. This time, we had to work from scratch and to start virtually with nothing in hand. Moreover, time was pressing and we got only a few months left. We were all very anxious.

***"In this case, teachers themselves are the main actors / curriculum developers ..."***

Secondly, we had to adjust our own thinking regarding the role of teachers in curriculum development: Traditionally, a top-down approach is being adopted for curriculum development in Hong Kong. New developments and/or revisions are initiated and coordinated by the Education Department, which are then disseminated to teachers via seminars, etc. In this case, however, it was we/ourselves who wanted to find out the inadequacies of the mainstream science curriculum and to supplement it by more appropriate topics and materials based on our practical teaching experience. That is, teachers themselves are the main actors/curriculum developers, facilitated by staff members from HKU.

*"... we spent our whole summer vacation in dedication to the Secondary 1 pupils whom we would be teaching in the coming academic year."*

Teachers participated in the project met several times during the summer vacation. As could be imagined, not every meeting ended up with fruitful results. We finally decided to work on two topics - 'living organisms' and 'how to turn cloudy water into tasty beverage'. We then divided ourselves into groups to work out the details and to prepare the necessary curriculum materials. This was how we spent our whole summer vacation in dedication to the Secondary 1 pupils whom we would be teaching in the coming academic year.

*"... as the chairman of the Integrated Science Panel, I had to face both 'external' and 'internal' problems."*

Upon joining this project, I as the chairman of the Integrated Science Panel, had to face both 'external' and 'internal' problems. Externally, this project involved three parties - our school, Ho Ngai Prevocational Secondary School and HKU. Since this was the first time that our subject panel was engaged in this kind of curriculum project, it took me some time to adjust to this kind of working relationship with external bodies. And so did my colleagues. Thus, I had to persuade my colleagues and to handle interpersonal relationships carefully. This constituted one of the internal problems. At the beginning, I did not feel adequate about my own involvement in the project. A lot of questions bothered me. For example: Is there something that the project is lacking? Is it support from the school? In what ways can our school support us? Is the number (two only) of schools participating in the project too small? Would it be better if more schools are involved in curriculum design? What is the role for each of the three parties concerned? The questions were so many and complex that I found it much more practical to spend the time on developing the curriculum.

Internally, our school has been established only for a few years and the relatively high turnover rate of science teachers was a concern for me. Since we had to start planning the next year's curriculum before the end of the current academic year, support from existing staff was indispensable. Though I anticipated that the curriculum for next year would be very challenging, interesting and rewarding, the problems were: Can teachers in my panel cope with this new challenge? Would they agree with me? Who, amongst them, would volunteer to take up this challenge? Would they be willing to abandon the teaching materials they are so familiar with, to implement a new curriculum of which the provision of teaching materials, the reaction of students, etc. are all uncertain to them? Furthermore, would the laboratory technician understand our requirements for the practical work? Would he have enough time to prepare for the labs?

***"The problem that concerned me most as the panel chairman was the medium of instruction."***

The problem that concerned me most as the panel chairman was the medium of instruction. In this project, all the curriculum materials were written in Chinese. It is generally agreed that learning through mother tongue would facilitate students' learning, thinking and discussion. This is particularly true for learning in science which requires active thinking. However, in our school, English is the medium of instruction. It was a special arrangement that during the project science could be taught in Chinese in Secondary 1. Still it was only a provisional arrangement. Upon completion of the project, this cohort of students had to revert to the mainstream science curriculum as well as to being taught in English. Hence, what sort of problems would this cohort of students be facing when they were promoted to Secondary 2? How should we help the students during the transition? Should the Secondary 2 teachmg syllabus be modified to suit the students? These questions are likely to be raised in the panel meetings.

Be it fortune or because of our determination, we had been able to implement the new curriculum as planned and we overcame many obstacles on the way. Actually there was still time left towards the end of the academic year and we managed to include one additional topic from the mainstream curriculum - cell and reproduction.

***"... as time went by they became more and more active ... This could hardly be seen in the mainstream science curriculum."***

I can recall the following characteristic features of the trial curriculum. During the lessons, we encouraged students to find out the answers for themselves by guiding them through the work instead of giving away *the* answers right away. We always tried to get students involved as much as possible, say to ask questions, to discuss problems, to design experiments, to carry out group discussions and to report their findings, etc. Initially students were a bit passive. But, as time went by they became more and more active in asking questions, solving problems, doing experiments and reporting to the class. Indeed, many students expressed that they had increasing interests in the subject. This could hardly be seen in the mainstream science curriculum. Knowing this, it released a lot of the pressure on us and we felt a bit more relieved psychologically.

***"Isn't that - working hard for bettering our next generation - a goal for us all educators?"***

The mainstream science curriculum has been in use for more then ten years now. In view of the rapid developments in technology, it needs to be revised though it was designed by curriculum development experts. In addition, many teachers are beginning to query whether a single standardized science curriculum could cater for the wide-ranging abilities of students, the differences among which seem to be widening more recently. The problem can be tackled in two ways - quantitatively and qualitatively. Quantitatively, we can trim the curriculum into a 'core curriculum' and an 'extension curriculum.' Qualitatively, we can try out new ideas including new topics and novel learning approaches so as to invigorate and motivate students' interests in learning science.

# A Way Out For Science Education

*Ko Cheung Chuen     Ho Ngai Prevocational School*
(Translated version)

*"Students regard practical lessons as games sessions, and teachers see practical lessons as something they wish to avoid as far as possible."*

Having taught Science for over ten years, I always feel that teachers teach with difficulty and students learn with difficulty. Students regard practical lessons as games sessions, and teachers see practical lessons as something they wish to avoid as far as possible. Although not all teachers and schools are like this, we cannot ignore the fact that this is what is really happening in some schools. To those teachers entrusted with the 'Academically Less Able' (ALA) students, the problem is even more acute. These students have no motivation to learn, low language abilities, poor self-image and little self discipline. As a result, during practical periods, the poor teachers are always exhausted trying to maintain order and discipline. Sometimes, to avoid accidents, they tend to revert to the traditional chalk and talk method of teaching used in the teaching of general science in the old days. This is a tragedy for junior science education in Hong Kong.

*"This is a tragedy for junior science education in HK."*

Last year, together with teachers from Ho Dao College, we joined the pilot project for the Science curriclum reform initiated by Dr. Nancy Law. Speaking from my own participation and experience throughout last year and the first half of this academic year, I feel that we have found a way out for science education for the ALA students.

*"... we have found a way out for science education for the ALA students"*

In this pilot project, we worked with three units on the F.1 Integrated Science curriculum: "Looking at Living Things", "Solution" and "Matter". We tailored it to match the abilities of our students by removing contents which were too difficult or boring, and supplemented it with activities and experiments that were more relevant and related to everyday life to stimulate student interest. In the unit "Looking at Living Things", we showed students a large collection of photos of various kinds of living things and asked them to compare their similarities and differences. This led on to the identification of characteristics of living things. Also, instead of studying snails, we asked students to bring to the school their own pets. This resulted in a surprising range of animals, including rabbit, guinea pig, parrot, Brazilian tortoise, gold fish, crayfish etc. For large pets like cats and dogs, students were asked to bring back photos of the pets instead.

*"... instead of studying snails, we asked students to bring to the school their own pets."*

During the lesson, students participated actively in describing the habits of their pets, discussing and trying to understand the characteristics of each animal. We also let students make their own favorite drinks in order to learn about solubility and factors affecting the rate of dissolving. We put an orange in a paper bag and asked students to guess what was inside the paper bag to teach about particle diffusion. To teach about the water cycle, we actually made rain in the laboratory. Through these, the learning atmosphere became much more active and lively, and students understood much better than before.

***"... To teach about the water cycle, we actually made rain in the laboratory."***

Another special feature of the pilot project was that students learnt through trying to solve problems. In teaching the purification of water, we started by asking students to design ways of purifying water all by themselves. Then we let them find out the feasibility of their own designs by actually letting them try out those designs in the laboratory. The methods of purification students came up with were full of imagination, e.g. filtering dirty water using a towel; filtering the dirty water first then boiling to kill germs; filtering first, then adding bleach to kill germs, followed by boiling afterwards. Amongst these various methods, the ones suggesting distillation and also another one suggesting filtering using a filter column made of sand and gravel, activated carbon and killing germs using UV light happened to be similar to the methods we have planned to teach them. Through designing their own experiments, students could easily understand how to treat dirty water. Whether the experiments designed by students work or not, during the problem solving process, they showed much greater motivation towards learning, they were much more interested and involved. They were able to learn much more effectively compared with the traditional method. During these teaching activities, I came to realize that even students who were labelled academically less able could be very creative and full of imagination too. It all depended on whether the teacher was able to provide the opportunity to bring the creativity out of these students.

***"... we let them find out the feasibility of their own designs by actually letting them try out those designs in the laboratory..."***

***"I came to realize that even students who were labelled academically less able could be very creative and full of imagination too."***

During the lesson, students had to co-operate with other students to investigate and solve problems. There were many opportunities for them to exercise their brains and to communicate their ideas to others. For example, they had to pretend to be a salesperson for water filter systems, they had to write their own science fiction, all these allowed them to express themselves.

Exercises like these helped to extend the students' potentials as well as to enhance their self-images. Since they were all fully involved in learning, there were few disciplinary problems during lessons.

The workload of teachers were necessarily increased during the pilot project. However, in order that students can learn effectively and build up a good foundation in science, so that they are better equipped to face the ever advancing scientific and technological world, some sacrifice is warranted. Students were not the only ones to gain, teachers benefited a lot too. We gained much by sitting together with teachers from other schools, discussing our curriculum, exchanging experiences and trying to implement the new teaching strategies. Students became more motivated, classroom discipline improved, teachers could teach more effectively. This project has definitely got results indicating that we are on the right track, however, there are also problems to be solved. It is a pity that only one or two schools are trying this out. If there are more schools and teachers involved, science education in Hong Kong would take on a promising new perspective.

***"Students were not the only ones to gain, teachers benefited a lot too."***

***"If there are more schools and teachers involved, science education in Hong Kong would take on a promising new perspective."***

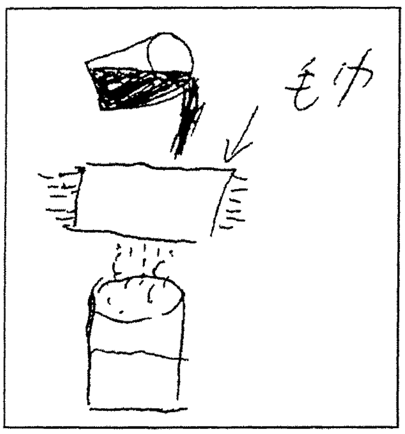
# Students' Learning Experiences & Outcomes From SMILE

# Three Cobblers put together can outwit a Wise Man

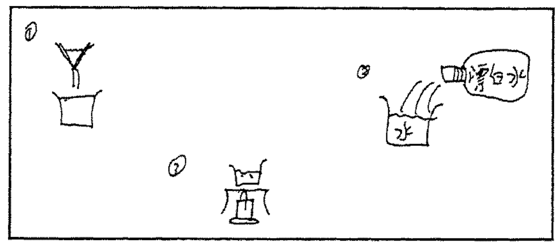
C.K. Wong

In the first lesson of the module on "Can Dirty Water become a Delicious Drink?", students work in groups to design ways of purifying water. The teachers did not provide them with anything other than a clear motivation for the set task by giving an introduction to the worldwide problem of water pollution and water shortage. Below is a selection of some of the students' proposals. How do you rate them? Are these practicable?

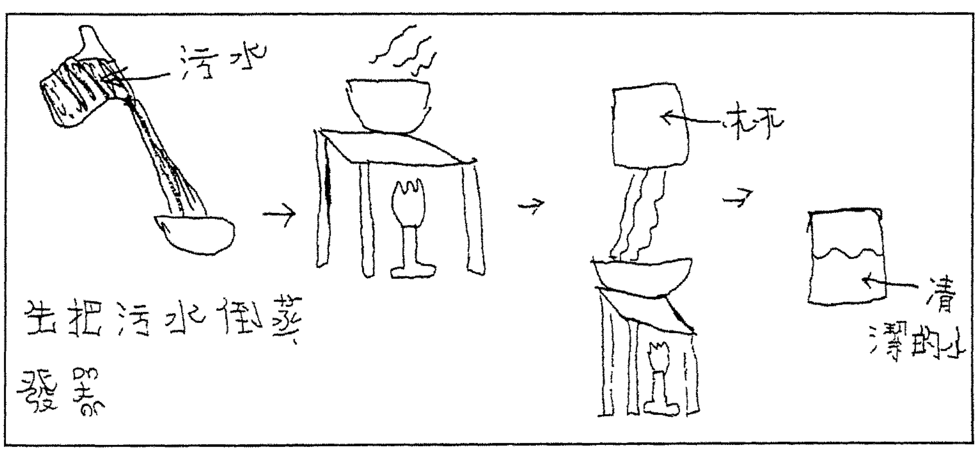
**Proposal A**




**Proposal B**




**Proposal C**




These proposals can be assessed from two different perspectives. If we require that the proposals provide designs that can be followed directly to produce purified drinking water these proposals probably all "*fail*". However, if we try to fathom the student's thinking that guided these designs, we might be in for a few happy surprises!

If we try and analyze the above three proposals from the latter perspective, what do you think we would be able to see? Proposal A is a rather innovative, though not too effective method of filtration. Proposal B has incorporated, on top of filtration, two different methods of sterilization: boiling and chlorination. Proposal C makes use of the concept of distillation. If teachers do not plan and teach their lessons on the assumption that students do not know anything about the subject matter to be taught, but start with these proposals and the thinking behind them, do you think that the teaching task would become easier? More importantly, such a teaching approach would help students to see the connection between science and everyday life and to realize that they do possess knowledge and skills that can contribute positively to their own learning of science. This should encourage students to have greater confidence in their own ability to learn science.

Do you agree with these views?

# More Than Comics:
# An Innovative Way of Understanding Students' Thinking

C.K. Wong, Nancy Law

Traditionally, the written word is the main tool for assessing student learning, e.g. multiple choice questions, fill-in-blanks or structured questions. However, there are many more formats and methods of assessing that might be more appropriate, depending on the purpose of the assessment. Drawing is one alternative form of assessment. It poses less constraints and may be able to elicit more abstract, tacit and deep-rooted understandings that students might not otherwise be able to express through words alone. Furthermore, as this format allows more creative expression, most students, especially those with poor language skills, will have greater confidence and less rejective feelings towards this kind of exercises. SMILE believes that a variety of assessment methods will enrich our understanding of students' learning.

The explicit aims for the module "Can Dirty Water become a Delicous Drink?" was to help students to gain a better knowledge of the methods of water purification and understanding of the concepts of dissolving and solutions. There was however, another key though more implicit aim, which was to orientate and encourage students to take on a microscopic perspective towards exploring the fundamental structure of matter. Thus, it would be very useful to find out if students have developed such concepts towards the end of the module. We have chosen creative science fiction comic story writing as the means for carrying out this exploration. Do you think this method is useful?

**Fig. 1 The task set for students**

**Science Fiction Competition**

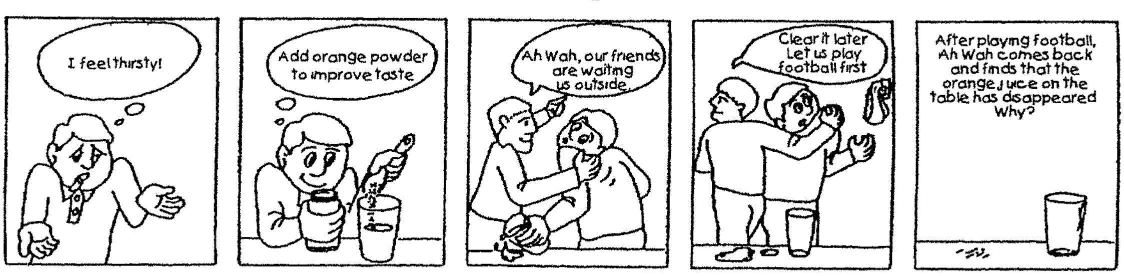
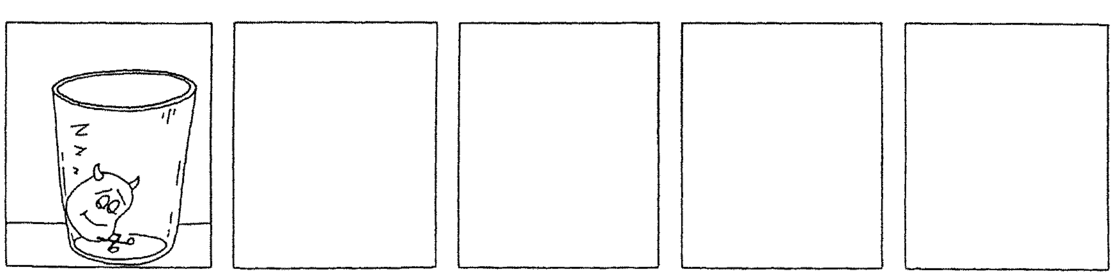



Image you are a micro-organism hiding in the cup and watching what has happened thoughout the whole process How would the world as seen by you be different from Ah Wah's? In the spaces provided below, draw the process again as seen by you.

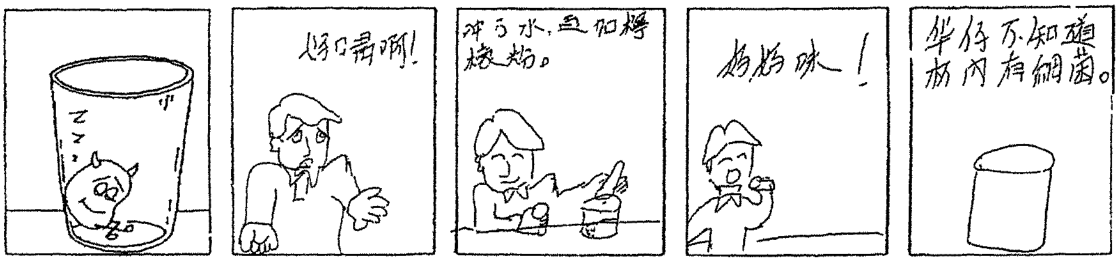


**What ideas do the students' comics express?**

A total of 126 student comic drawings were collected. Upon careful analysis, we find that only 19 of these (15.1%) expressed ideas that could not be clearly identified or categorized. The rest could be categorized into six different groups of views. These are described below.

The first group of comics focussed on depicting the feelings of the person in the comic. Even though the question clearly asked the students to imagine themselves becoming a micro-organism and to show in their drawing what they would then be able to see, this was clearly missed by the authors of this group of comics. What this group of authors were concerned about were the circumstances and feelings of Ah Wah (the boy), such as: Will Ah Wah become sick after drinking the glass of orange juice that contains micro-organisms? They failed not only to understand the world around them from a microscopic perspective, they actually overlooked the key question in the stem: "The orange juice on the table disappeared. Why?"

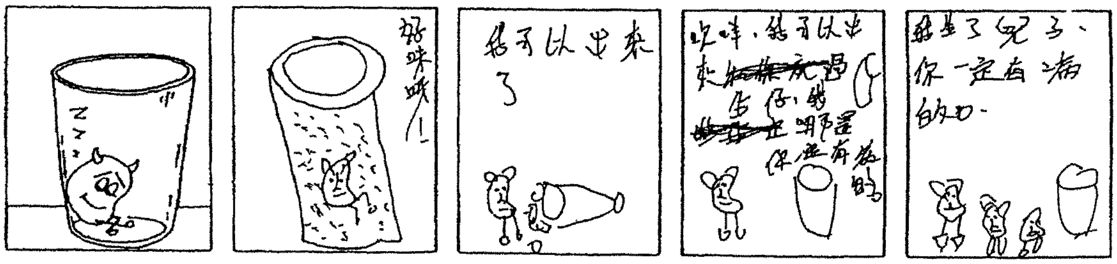
This group accounts for 16.7% of the comics analysed




(I feel thirsty!) (Pour water and then add lemon powder) (It tastes good!) (Ah Wah don't know there are bacteria inside)

<u>Example of Comics in Category I</u>

The second group of comics clearly expressed visions of the world as seen from a micro-organism's perspective, focussing on the feelings and concerns of the micro-organism as a human-like animated object. At the surface, this group of comics are adhering to the requirements of the question. Do you think comics such as the one depicted below indicate a successful attempt at understanding the material world around us from a microscopic perspective?



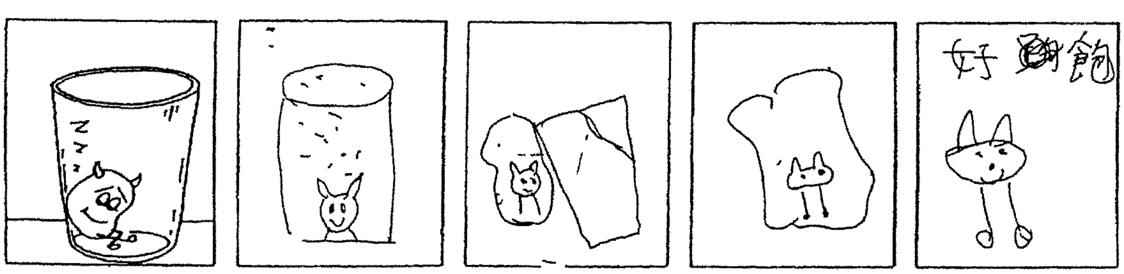

( I like the taste!) (I can go out ) (I go out and will breed offspring) (I have children and you will get sick)

<u>Example of Comics Category II</u>

If we inspect the comics in this category carefully, we will find that although the author has assumed the physical characteristics of the micro-organism, the theme is still that of the sentiments and feelings of the human world, such as: the micro-organism wishes to go outside of the glass to play with its friends, the micro-organism wants to harm humans through breeding more micro-organisms. Therefore, judged from a more critical perspective, these comics are still not demonstrating an ability to understand the physical world around us from a microscopic perspective. Furthermore, like the first group of comics, this second group again did not explain or even touch on the key question of why the orange drink had disappeared. This category comprises the biggest group, accounting for 30.2% of the total.

Reading the question again carefully, we can see that it poses two requirements on the students. The first is to ask students to imagine themselves as a micro-organism, with a view to bringing them closer towards a microscopic perspective of thinking about the world. The second one is to ask students to explain why the orange drink disappeared. The purpose of the latter is to get students to formulate their views on the process and mechanism for the disappearance of liquids when exposed to air. Science is built upon careful observations and the setting up of models/hypothesis to explain observed phenomena. Modern science explores and explains the world around us from the perspective of an objective outsider. Human sentiments and feelings are considered to be irrelevant to our understanding of the physical world around us. Such implicit values and perspectives are often not recognized or taken account of in science teaching. However, the fact that the above two groups of comics failed to grasp the key problem of why the orange drink disappeared indicates that these students are still not some distance from meeting the demand in science to set up and test hypotheses about the behaviour of the world around us. Whether a student can come up with a microscopic model to explain the disappearance of the orange drink is a higher level development. All of the following four groups of comics are, on the other hand, able to propose a reason for the disappearance of the orange drink, even though they may not be able to come up with a microscopic model of explanation.

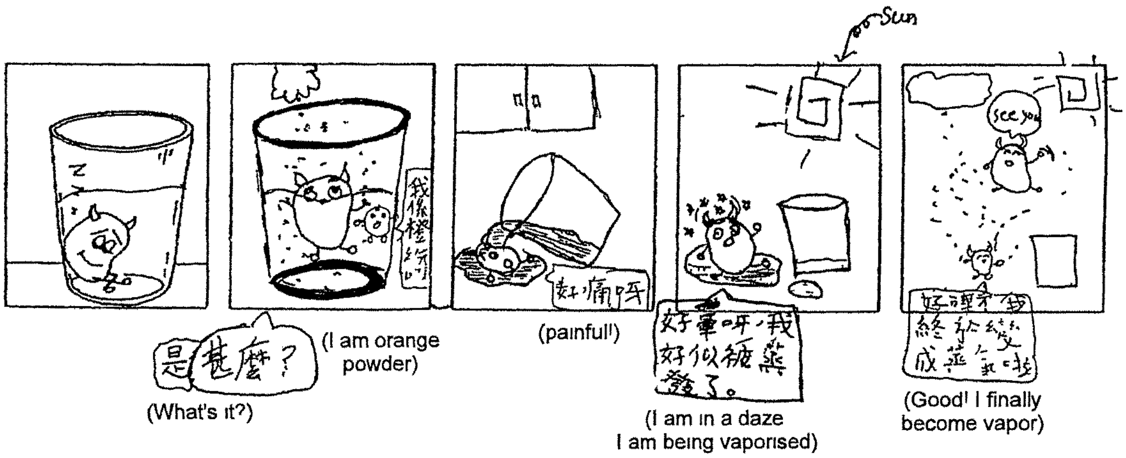
The third category (about 10.3%) attributed the disappearance of liquids from the table top to external factors like being blown away by air or drank by the micro-organism. Superficially, these are acceptable hypotheses. However, they did not account for the observed properties of water nor relate to the changes of state of water that they have learnt in the module. In other words, the students did not link the knowledge gained from the module to their competiton of this drawing task.




(I'm pretty full)

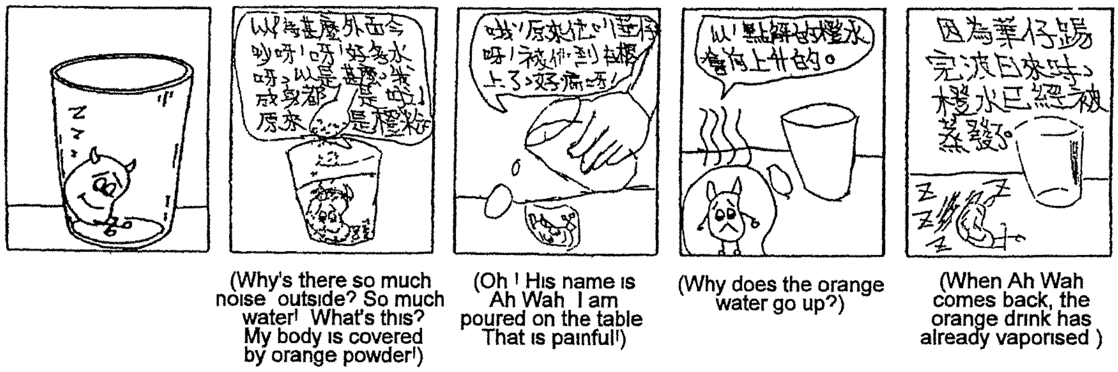
Example of Comics in Category III

The fourth category (26.2%) used learnt scientific knowledge to explain why the orange drink disappeared. The drawing and/or the accompanying text highlight the concept of evaporation. However, they fail to distinguish the differences in behaviour for water, orange powder and micro-organism during the process of evaporation and assumed that these would all disappear due to evaporation.



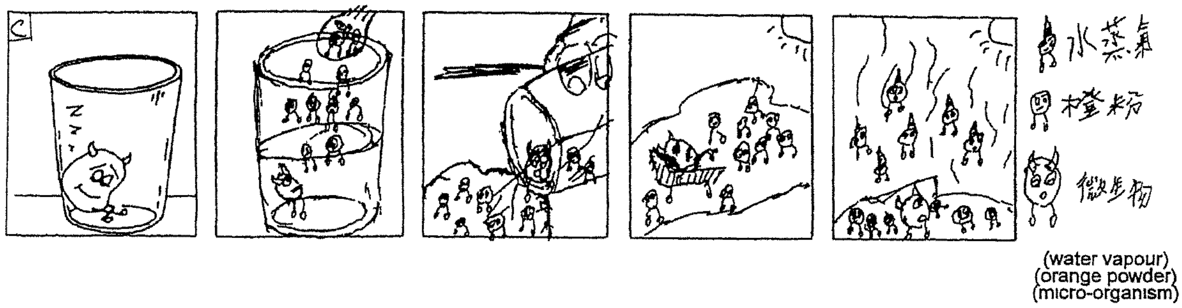

Example of Comics in Category IV

The fifth category (12.7%) was able to combine learnt scientific knowledge with the drawing task correctly. They show clearly that only water can be evaporated. The fact that these students can do this in such a loosely directed task indicates that they have a relatively deep understanding of the learnt concepts




Example of Comics in Category V

In a few of the 126 comic drawings we collected, the creativity and depth of understanding shown were unexpectedly outstanding. Even before the teacher started talking about the atomic structure of matter, these students were already clearly indicating an attempt to use a particulate model to explain macroscopic phenomena. They already have extremely good mental preparation for the learning of atomic theory and would be able to grasp it with minimal teacher guidance.




Example of Comics in Category VI

Table 1. A Summary of the different Categories of Comics

| Category | Description | No. of Drawings | % |
|---|---|---|---|
| 0 | Cannot be interpreted | 19 | 15.1 |
| I | Focus on human feelings & sentiments (Macro-view) | 7 | 5.6 |
| II | Focus on the feelings of the (humanized) microbe | 38 | 30.2 |
| III | Water being moved from one location to another | 13 | 10.3 |
| IV | Evaporation, but not only of water | 33 | 26.2 |
| V | Evaporation of water only | 13 | 10.3 |
| VI | Embryonic beginnings of a particulate model | 3 | 2.4 |
| | | 126 | 100 |

Do the different categories of comics really indicate a different level of learning outcome in science?

It is not possible to use a simple score to grade the comics drawn by students, but can we set up some framework or criteria to assess the students' understanding of scientific concepts reflected in these drawings? The framework describe above is one possibility. However, this form of assessment is very different from the conventional methods that we are used to. How can we be sure that the different levels of understanding described above aren't simply wishful interpretation?

To explore this question, we tried to compare the examination score for these seven groups of students. In order that the scores used can reflect more objectively what students might learn in a traditional learning environment, only the scores for the multiple choice questions were used in the comparson.

Table 2. Examination score for students producing the different categories of comics.

| Category | Description | Means of MC scores |
|---|---|---|
| I | Focus on human feeling and sentiments (Macro-view) | 6.3 |
| II | Focus on the feelings of the micro be | 6.6 |
| III | Water removed through external machamisms | 6.9 |
| IV | Evaporation but only of water | 7.8 |
| V & VI* | Evaporation of water or particulate model | 8.9 |

*As there are only very few cases in Catergory VI, it has been combined with Caterory V in the calculation of Mean

From the above table, we can see that the scores increase steadily as one move towards categories reflecting better understanding of the concepts. This is an unanticipated outcome that is extremely exciting indeed. This gives us confidence to believe that the comics reflect deeper levels of differences between students in their learning of science. It should help us in understanding students' learning difficulties in science as well as helping students to move towards deeper levels of understanding.

**Students' Comics as Teaching Resource**

The comics produced by the students are useful not only as a means for teachers to better understand students' thinking, they are also useful teaching resource materials. This task can be organized as a competition the result of which is determined through voting by students. The teacher can guide students to compare the comics from different perspectives and to draw their attention to the thinking that is represented in them. The teacher can also ask students to put down on their ballot sheet why they think a particular comic is outstanding. In this way, the comics representing more developed ways of thinking can be used to influence other students. As these are student creations, they would be more easily identified with and accepted by other students than the "hard" orthodox explanations used in textbooks.

**More than comics**

Science as a discipline has its own system of thought and methods of working. To be effective science education is not just the transmission of knowledgebut often has to involve changing the students' ways of understanding the world, the methods and perspectives used in framing and solving problems. We should thus explore the use of different means of assessing the cognitive development of students, e.g. comic drawing, story-telling. This would help to make our teaching more targetted at students' thinking and provide us with useful resource materials for classroom discussions and subsequent teaching.

# Making Stubborn Stones Nod: Students' achievements through SMILE

C.K. Wong, Nancy Law

During the pilot implementation of the SMILE approach, in addition to efforts to make the learning experience interesting and to build up students' motivation and confidence in learning, we were very keen to use different ways to monitor different kinds of learning outcomes achieved by students in the process, such as the mastery of some relatively abstract scientific concepts. We are very pleased with our findings so far and would like to report it briefly here.

**Comparing Plants and Crystals**

Through the unit "Can Dirty Water Become a Delicious Drink?", we hope that students can be encouraged to think more about the structure and composition of matter. Prior to this unit, the students had already finished the unit on "The World of Living Things" and thus should have some understandng of the characteristics and differences between living and non-living things. At the end of these two units, we administered a short test on students to find out whether they were capable of more creative understanding and deductions based on taught content. The question used in the test was: ***"Crystals grow during the process of production, plants also grow under suitable conditions. What are the similarities and differences between these two kinds of growth?"*** To answer this question well, one has to have a deep understanding of the contents of the two taught units. The students' answers are very varied and some may not have grasped the key differences between the two kinds of growth. However, many more of the answers are reflecting various levels of understanding. Some compare the two kinds of growth from the perspective of the conditions required for growth, for example:

> *"Crystals are man-made, depend on temperature, strength of the solution. Plants grow of itself and environmental factors."*
>
> *"Plants need sunlight to grow, and crystals do not need sunlight."*

Some consider this question from the perspective of the difference between living and non-living things:

> *"The growth of crystals is not real growth It's only a grouping together of other crystals But the growth of plants is from the making of food under the sun."*

Some tackled the comparison starting from the characteristics of crystals:

> *"Plants grow from the earth, also blossom, change in shape Crystals grow gradually in water, the shape remains the same as in the beginning."*

Some students even reached levels of understanding beyond that taught by the teachers:

> *"Crystals grow because of the grouping together of the same kind of particles in the production process. Plants grow naturally after taking in nutrients "*
>
> *"Crystals grow in the process of production because of the regular lining up of many particles. Plants take in different kinds of particles Both crystals and plants will grow bigger. Both plants and crystals take in particles to grow."*

**Students' performance in traditional examinations**

Besides using more innovative ways of probing students' understanding, we also wanted to find out if students in the SMILE pilot schools would be different in their performance in traditional examinations compared to other school. The two pilot schools used the same exmaination paper for their final integrated science examination. We invited another school to give a portion of the examination paper to their students to try. The school selected has the majority of its Form One intake in Band One (i.e. the top ability group) and is in the same district as the pilot schools. This school acts as our reference group in this preliminary study. The following table lists the mean scores for the items that all three schools attempted.

Table 1. Summary of examination results for the pilot schools and the reference school.

| | Description of question | Max. score | Mean score of School 1 (272)* | Mean score of School 2 (179)* | Mean score of control (band 1) School (256)* |
|---|---|---|---|---|---|
| Q10 | ingredients of drink | 7 | 1.65 | 2.09 | 3.15 |
| Q16A & B | function of water filter | 8 | 3.97 | 4.16 | 4.56 |
| Q16C | testing water purity | 3 | 0.07 | 0.28 | 0.04 |
| Q17A | use of thermometer | 4 | 1.28 | 1.59 | 1.38 |
| Q17B | reading of thermometer | 2 | 1.65 | 1.66 | 1.69 |
| Q17C | plotting graph | 4 | 3.13 | 3.09 | 3.61 |
| Q17D | reading graph | 8 | 2.86 | 3.08 | 3.66 |

* Number in brackets indicate the total number of students in the school.

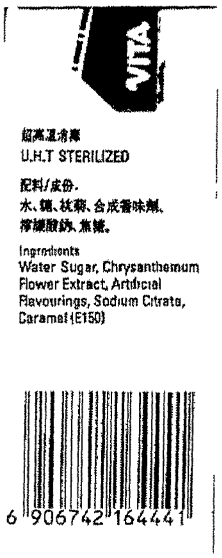
Statistical analysis shows that the performance of the control school students are significantly better than the two pilot school students at the 0.01 level for only three items. The three items are Q10, Q17C and Q17D.

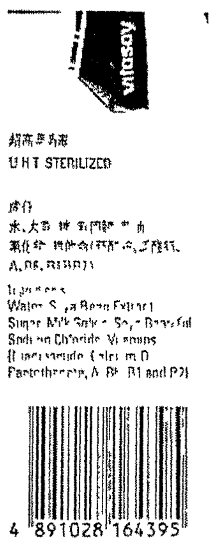
Q10 requires the students to categorize the ingredients of a soft drink. This requires students to have analytical power. Q17C and Q17D requires students to fit a curve and use the information on the curve to answer some questions. Good mathematical skills is needed to accomplish this. The other four items are related to experimental skills and some everyday applications. The results show that students in all three schools do not differ significantly in their performance in these four items.

Given that the student intake in the two pilot schools are mainly academically low achievers, such results are indeed encouraging.

(Appendix: The examination items Q 10, Q16 & Q17)

Q10. The following is the composition of a soft drink as shown on its package.




Identify for this drink which is/are its:

i. solution ______________

ii. solute ______________

iii. solvent ______________

Q16. A. The core of commerical water filters usually has two main components: the filter net and activated carbon. Explain in the space below their respective functions.

i. Filter net ______________ (3%)

ii. Activated carbon ______________ (3%)

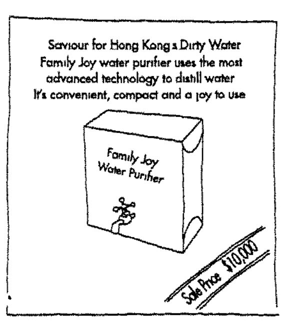
B. Some filters are fitted with ultraviolet lights. Why?

______________ (2%)

C. There are different kinds of water filters selling at different prices on the market. How can we find out their effectiveness in purifying water?

______________ (3%)

D. The following is an advertisement introducing a new product, "The Saviour for Hong Kong's Drinking Water ".




Would you consider buying this new product? Why? (4%)

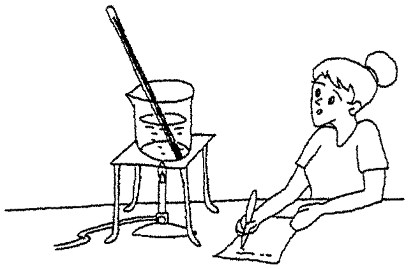
______________

______________

______________

Q17. Betty is doing an experiment to change a substance from a solid to a liquid, and then a gas.

A. The following diagram shows how Betty set up the experiment and read the thermometer.



Can you point out the two mistakes shown in this diagram? (4%)

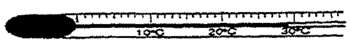
(i) ______________________________

______________________________

(ii) ______________________________

______________________________

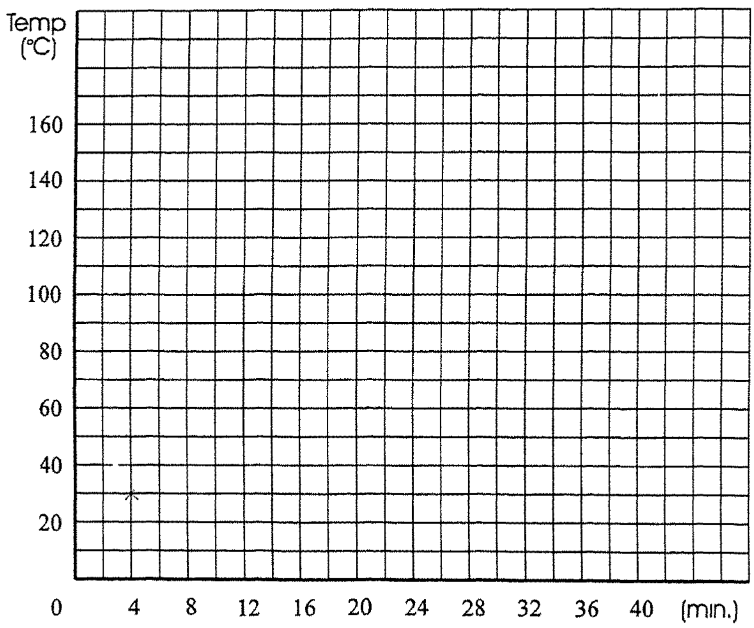
B. The temperature reading shown in the diagram below is ______(2%)




C. Betty heats up the substance in the beaker to change it from a solid to a gas. She recorded the changes in temperature in a table.

| Time (min ) | 0 | *4* | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
|---|---|---|---|---|---|---|---|---|---|---|
| Temp.(°C) | 10 | ***30*** | 50 | 50 | 50 | 80 | 110 | 140 | 140 | 140 |

Use the above data to draw a graph showing the relationship between temperature and time. (4%)
(The italicized data point in the table above has already been plotted).




D. Use the graph to find answers to the following:

(i) The boiling point of the substance is ______________________. (2%)

(ii) The time taken for the solid to change completely into a liquid from the point when the solid just started to melt is: ______________. (2%)

(iii) What was the approximate temperature two minutes after heating has started ?_______ (2%)

(iv) How long did it take to heat the substance to 110°C? ______________ (2%)

# Part II

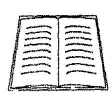
# Teachers' Guides and Students' Worksheets

Nancy Law & C.K. Wong

The following is a key of the symbols used in the following section:

 teachers' guide

 experimental worksheet

 reference materials for students

 worksheets for consolidation

# Can Dirty Water Become a Delicious Drink?

## Curriculum Guide for Module:
## "Can Dirty Water become a Delicious Drink?"

**Module Theme:** This module focuses around the problem of water. It consists of 9 lessons, each being more or less like a topic, varying from 1 to 4 class periods. It starts with the purification of water ( a common problem that students can understand and are concerned about), and asks students to design their own methods of purification (lessons 1, 2 &3). The teacher then leads students through the topics filtration, boiling and distillation, three common methods of water purification (lessons 4 & 5). It is expected that these three methods are very familiar to students and that these would have already been used in the students' own designs. This way of introducing the topic should thus arouse students' interest and also promote their self-confidence in their ability to do and learn science. Further, through the examination of the impurities still remaining in the water, this module also tries to stimulate students' interest and to start thinking about the microscopic world of matter. This can begin from unit 3 & 4 with thinking about what is matter composed of, and then through their experience and awareness of particles of different sizes and through investigations of boiling and evaporation, lead to some idea of particle motion. The introduction of the filter plant and desalination plant in Hong Kong (lesson 6) and the water cycle (lesson 7), is aimed at further enhancing students' knowledge of the application of the learnt concepts and processes as well as promoting further thinking about the microscopic view of matter (esp. lesson 7). The next lesson (8) on making delicious drinks introduces the concepts of solution and solubility through the actual making of drinks, and further consolidates the understanding of the concepts solubility and rate of solution through more detailed experimentation. The last unit on crystallization finishes the module with looking at how one may recover dissolved substances from a solution and thereby provide an opportunity not only to know about the fascinating world of crystals but also to further stimulate their thinking about what makes up matter and how they are structured.

**Module outline**

| Lesson | Focus | Activities | Concept | Knowledge | Skills | Attitude |
|---|---|---|---|---|---|---|
| 1 | Clean water as a scarce resource and how to purify water | * watching video on problem of lack of clean water in developing countries/in HK<br>* designing a method of cleaning water for drinking<br>* read short notes on impurities present in water | * there are impurities in water that would be harmful to health when taken in | * a faint knowledge that there are three kinds of impurities in water: soluble, insoluble and micro-organisms | * use the knowledge they have gained from within and outside school for designing a way to purify water<br>* work in groups to design an experiment | * awareness that water is a scarce resource that should be valued and not taken for granted<br>* awareness that technology can be used to enhance our quality of life<br>* awareness that they do have valuable knowledge |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | Purifying water | * purify water using students' own design from the previous session<br>* discuss what impurities the various methods may be able to remove<br>* students select from the various methods used one they think is the best and write down why they think so | * a beginning awareness that while some impurities are visible, there are some that are invisible | * some initial knowledge of the ways of purifying water from the different designs appearing in the laboratory | * ability to carry out procedures they designed earlier which may include filtration, boiling, distillation and/or disinfection | * building up confidence in their own ability to design useful procedures and to carry them out. |
| 3 | Is this water clean? | * students to think about how to test for water purity and to write down in their worksheet and to discuss them<br>* compare purity of different water samples using a projection microscope and evaporation<br>* compare their own choice of best method with the test outcome<br>* complete worksheet detailing their own method, and to evaluate and improve on their own method | * a clearer conception of the three kinds of impurities found in water: that there are living organisms as well as other invisible impurities | * a knowledge of the common ways of testing for the three different kinds of impurities<br>* understand the use of microscopes for seeing objects that are otherwise too small to be seen<br>* to know that some impurities are too small to be seen even under the microscope | * recording investigation result (of the purity test for their own water sample)<br>* evaluate design and use knowledge learnt to further improve procedure | * to recognize that procedures can always be improved and still value their own work and knowledge |
| 4 | What kind of filter do we need? | * compare the effectiveness of different kinds of filter columns in terms of removal of the three kinds of impurities<br>* compare the effects of using UV light and chlorination for disinfection<br>* observe and compare the passage of milk, Chinese ink and salt solution through filter paper and charcoal | * develop some frame-work of visualizing impurities as having different sizes and that the effectiveness of filter columns partly depend on the effective size of the holes in the columns | * know that charcoal is different from other filter materials in that it can remove coloring materials from a solution<br>* know that both UV and chlorine can be used for disinfection and that dissolved chlorine can also affect us | * acquire further skills in filtration and choice of filter materials | * awareness that technological 'cures' frequently also has side effects. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | * view video on different kinds of commercially available filters and their structures, discuss and compare these with the ones they have used earlier<br>* view video on the chlorination process of swimming pools<br>* read newspaper cutting on fear of infection through public swimming pools | | | | |
| 4b | Making a commercial advertisement for a filter | Advertising competition<br>* students work in groups to design an advertising leaflet for a commercial filter (given some basic information and the actual filter) OR<br>* prepare and videotape a TV program advertising a filter (5 min max.) (as supporting materials, show a videotape leaflet from a commercial vendor) | * consolidation of the concepts on kinds of impurities and methods of elimination learnt earlier in this unit and to use that framework to understand the working principles of commercial filters | * some acquaintance with the structures of modern commercial water filters | * communication skills - skills to elaborate and explain workings of sth. unfamiliar using learnt science concepts<br>* skills to analyze the strengths and weaknesses, including economic considerations for different devices | * awareness of the economic motivation behind many scientific and technological developments<br>* awareness that what advertisements say may not reveal the complete picture: what is said is at least as important as what is not said |
| 5 | Boiling and evaporation | * design and conduct an experiment to find out how water and steam temperatures vary with heating time<br>* discuss the difference between boiled water and distilled water and effects of their use as regular drinking water<br>* discuss the difference between water and water vapour | * the purest water may not be the best for health | * temperature of water does not change during boiling and is the same as the temperature of the steam it produces | * ability to design & conduct simple expt. to measure water & steam temp: know that thermometer should not touch heated container and avoid build up of steam pressure | * start wondering about what's the essence of matter - what's the difference between water and steam since the two are inter-convertible. |
| 6 | Our drinking water in HK | * watch video (ETV) on HK water filter plant and the former desalination plant<br>* complete related worksheet after watching for consolidation<br>* discuss the similarities and differences between these industrial processes | * to develop a deeper understanding of the conceptual framework on water purification through seeing the framework's application to an industrial process | * knowledge of how the water filter plant in HK works | * ability to recognize the basic similarity between processes that take place on very different scales | * further awareness of the usefulness of what they have learnt in class to actual technological applications that affects everyone in HK |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Making rain | perform a simple experiment to observe water cycle operating inside a softdrink bottle. Students will see tiny particles of water droplets moving in the convection current. | * relates the change of state observed earlier with the water cycle operating at a much larger scale - rain & clouds | * knowledge of the water cycle and that vaporization does not need to take place at boiling point | * observe and note that the movement of water vapour in the convection current and to note the colour differences in the condensation process. | * further wondering about what makes up matter (water in particular), hopefully some particle model starting to build up |
| 8 | Making delicious drinks | students work in groups to make various hot and cold drinks and to write down the recipes for each of them<br>discuss the various methods (of making solutions) and why these were necessary | * first introduction to concept of solution and solubility and relate these to the drinks we make.<br>* vague awareness of relationship to temp. & stirring. | * knowledge of the terms: solution, solute and solvent and be able to identify these in relation to drinks | * ability to make solutions and be able to vary temp and use stirring to make solutions of desired strengths | * develop interest in science and to see it as relating to even common tasks that we do every-day |
| 9 | Crystallization | look at some samples of crystals made in the laboratory<br>watch video on how to prepare crystals<br>work in groups to prepare a copper sulphate crystal<br>watch the growth of different crystals through a projection microscope<br>watch video on naturally occurring crystals<br>complete worksheet on crystallization - elaborating on difference between plant growing and crystal growing | * concept that many materials exist in crystalline form<br>* crystals of the same material may vary in size but would be identical in shape | * knowledge that after the solvent evaporates from a solution, the remaining solutes would be in a crystalline form | * be able to grow a crystal of a pure substance when given a solid form of the substance | develop an appreciation for the beauty of the natural world through an introduction to various man-made and naturally occurring crystals.<br>* further promote the thinking that hopefully has begun on the micro-scopic view of matter: why do crystals always keep the same form during its growth? |

# Lesson 1 The Source of Life - Water

(Suggested time: 1 period)

This lesson is crucial to the success of the module as it sets out the focus or theme, which is how to make delicious drinks out of dirty water. The most important aim of this lesson is to help students realize that the shortage of clean water is a major problem faced by many people and thus how to make dirty water drinkable is a realistic and important technological task.

A good way to start the lesson is to use video clips and newspaper cuttings describing problems relating to shortage of clean water either in Hong Kong or elsewhere in the world. One possible resource is a short film by World Vision on water shortage and water pollution problems in the third world (approx. 10 minutes. The last section, being promotions of the organization, can be omitted).

The teacher should follow this up immediately by showing a sample of dirty water* and asking questions like:

- Is this water drinkable?
- Would you be willing to drink this water? Why not?
- If this is the only water available where you live, how would you purify it until it is safe to drink?

After a few minutes of warm-up discussion, issue worksheet W1A and let students split up into groups to discuss and design what they deem to be workable methods of purifying water. The teacher should point out that, in the next lesson, students would have a chance to implement their own designs and compare the purity of the resulting water to see which group's purified water is the safest to drink.

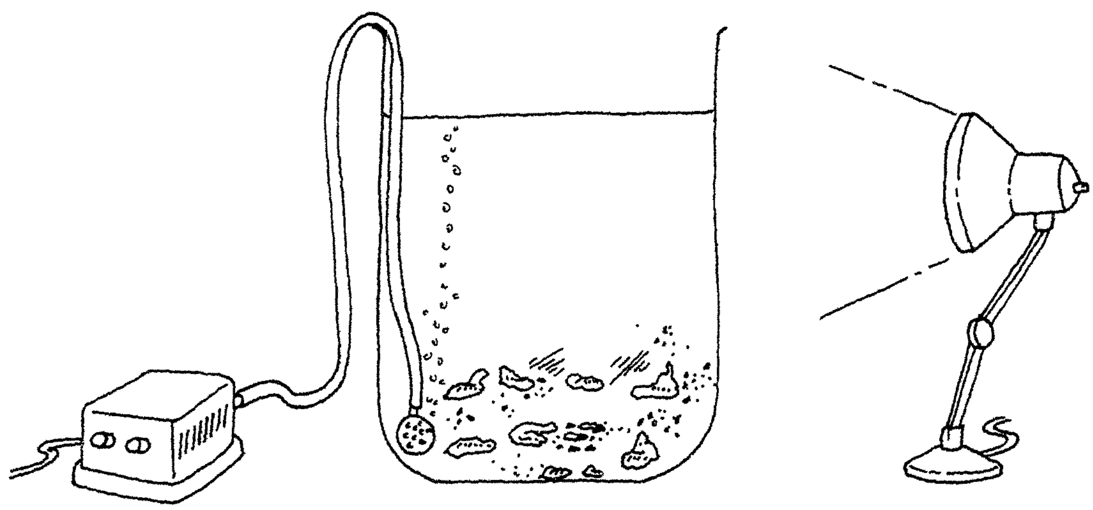
When collecting the finished worksheets at the end of this lesson, the teacher should check with students to clarify details in the design so that appropriate materials and equipment can be prepared for carrying out the purification according to their own design in the following lesson. The teacher may also select suitable items mentioned in the design and ask the students to prepare and bring them in for use in the next lesson.

Before dismissing the class, distribute Reference Material W1B, and ask students to read it before the next lesson.

After the lesson, the teacher needs to collaborate with the lab technician(s) to provide equipment for the students' designs. Since the methods proposed are probably amongst the three most common methods, it is believed that there will be no great difficulty in preparing the materials. If there are problems with the actual preparation, the pupils' design can be modified.

* To ensure success in the water purification experiments, it is important to maintain a supply of coloured dirty water with a variety of micro-organisms. A suitable source is pond water. Colour can be intensified by collecting more of the natural debris around the pond, e.g. squashed dead leaves. The teacher should experiment with different compositions of the dirty water to ensure that the desired results in subsequent experiments will be achieved.

The water so collected have to be properly maintained to ensure that the living organisms will stay alive. This can be done by pumping air through the water and shining a lamp onto the water to ensure that the minute plant organisms can carry on photosynthesizing and thus maintain the food and oxygen cycle in the water ecosystem.



## W1A WE NEED WATER

Group : ________ Date : ________________

Group members : ________________ ________________

________________ ________________

________________ ________________

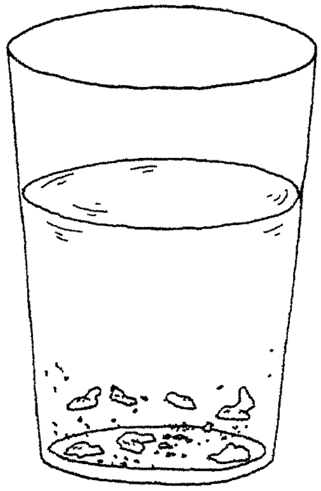
Water is the source of life, and is necessary for our everyday life. However, we may not always be able to get clean water.
Can you design a way of purifying dirty water so that it becomes drinkable?
Please show your design using an illustrated diagram and explain the procedures briefly in words.

Set-up for Water Purification

Materials needed:

Purification procedure:

## W1B SOURCE OF LIFE - WATER



If you drink this glass of water, you may die of cholera infection. If you do not drink it, you may die of thirst.

***-This is a problem faced by millions of people in the third world countries everyday.***

You may think that human beings would not be worried about the shortage of water.

Three quarters of the earth's surface is covered with water. However, the life of millions of people are in danger because of the shortage of water.

There are regions even within many developed countries that do not have enough water resources. In developing countries, many suffer not only from the lack of water: even the limited water resources they have may be seriously infected with bacteria.

Every year, there are over ten million people who die from the lack of water or water-borne diseases. Common causes of death are:

* Cholera, typhoid, hepatitis and other infectious diseases caused by polluted water arising from poor sanitary conditions.
* Scabies, leprosy, trachoma and other skin diseases caused by the lack of clean water for washing purposes.
* Amoebic diseases and other parasitic diseases caused by drinking unclean water.
* Malaria, yellow fever, sleeping sickness (caused by the African tsetse fly) and other diseases carried by insects that breed in dirty water.

Children are often the main victims of problems caused by the lack of clean water.

There are three main kinds of impurities found in water:

1. ***Impurities that are insoluble in water***, for example, sand, rock fragments, waste paper, plastic bags, etc. Fuel oil leaking into the sea from ocean liners also belongs to this category. This kind of impurity is easiest to detect.

2. ***Various kinds of micro-organisms***, including many kinds of single-cell organisms most of which are disease-causing bacteria. These are too small to be seen with the naked eye and requires a microscope to be observed.

3. ***Impurities soluble in water***. These can be coloured or colourless, smelly or odourless. Most industrial pollutants belong to this category and contain poisonous or carcinogenic (cancer-causing) substances harmful to human and other living organisms.

# Lesson 2 The Purification of Water

(Suggested time: 2 periods in laboratory)

This lesson is a follow-up of the first lesson, and the main purpose is to allow students to actually carry out the water purification process designed by them. This is very important as they own their design and in itself provides a strong motivation for them to follow up and find out whether their method is a good one and whether it needs improving in anyway. This is in line with the idea that teaching has to take advantage of and build upon students' prior knowledge.

Before performing the experiment, the teacher may ask students if they have problems in understanding the reading material W1B and make sure that students know which are the 3 main types of pollution in water. Most importantly, the teacher must remind students to attend to issues of hygiene in this experiment, especially of the need to wash hands after the experiment.

Due to the fact that the experiments are done according to the pupils' designs, a little more preparations is needed, and some necessary refinement may be needed. This is to be briefed at this moment to the students. Every group should get back their W1A Worksheet (with the necessary alterations detailed on the sheet), and carry out the designed purification process.

After the experiment, each group should provide a small sample of purified water* (each sample should be labelled with the group number and names of the group members) for comparison with other groups. The comparison will be carried out in the next lesson as a kind of competition in the next lesson (unless there is sufficient time left during this lesson). Also, each group should hand in their W1A worksheets to the class monitor to be pinned up on the class noticeboard in order for each class member to understand what methods the other groups have used in their designs. If there is still time after the practical work is completed, you may arrange for some of the groups to present their method of purification to the whole class.

Distribute Worksheet W2A as homework. Students should include in their response in Section 2 some of the methods used by other groups and what impurities they think those methods could remove. Students should then write down in Section 3 which of the listed methods they think is the most effective.

* Ideally, the next lesson should take place immediately or not long after this one, or else the micro-organisms in the samples would die. Oxygen may be pumped into the water daily so as to lengthen the life-span of the micro-organisms

Date : ____________________

Name : ____________________

# W2A PURIFICATION OF WATER

## 1. Water Pollution

What kinds of impurities can be found in water before purification?

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

d. ______________________________________________

## 2. Methods of Water Purification

What methods can be used to purify water? Please list below some possible purification methods and the impurities that each method can remove.

| Method of Purification | Impurities Removed |
|---|---|
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |
| ____________________ | ____________________ |

## 3. Which Method is the Best?

Which one of the methods listed above do you think is the best? Why?

______________________________________________

______________________________________________

Date: ____________________

Name: ____________________

# W3A IS THIS WATER DRINKABLE?

## 1. How do we know whether a sample of water is polluted or not?

There are three main kinds of impurities in water: insoluble dirt and suspended particles, micro-organisms and soluble substances. How can you test whether each of these impurities are present in a sample of water? Describe how your test works.

| Impurity | Method of Testing |
|---|---|
| **A. Dirt and suspended particles insoluble in water**<br><br>(Common sources for this kind of pollution are:<br>____________________<br>____________________<br>____________________) | |
| **B. Micro-organisms**<br><br>(Common sources for this kind of pollution are:<br>____________________<br>____________________<br>____________________) | |
| **C. Impurities soluble in water**<br><br>(Common sources for this kind of pollution are:<br>____________________<br>____________________<br>____________________) | |

2. **How did You Purify Water?**

Explain briefly below the method of water purification you used.

3. **Is the water you purified drinkable?**

From results of the test, what impurities did your purification method remove?

What impurities still remain in the water? Is the water drinkable?

What method can you use to remove the remaining impurities?

# Lesson 4 What Sort of Filter do We Need?

(Suggested time: 4 periods. Ideally two double periods in a laboratory.)

Lessons 4 and 5 aim to consolidate the knowledge and skills on water purification that have been developed in the last few lessons and further formalize and extend them. This is an example of the scaffolding idea in curriculum development where one starts with something that students care about and can contribute to and extend their understanding through building on students' prior knowledge.

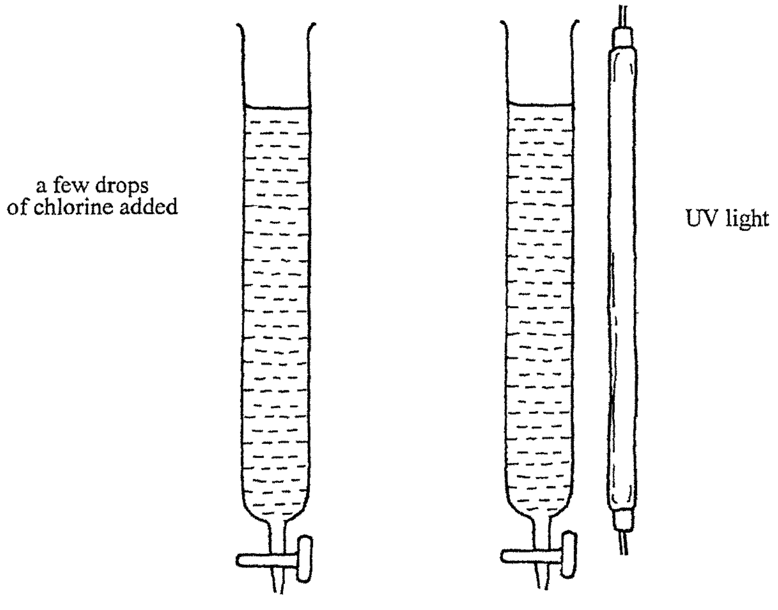
Lesson 4 compares the structure and functional characteristics of different filters. It aims not only to enhance the pupils' understanding of the filtration process and the different kinds of materials that can be used as the filtration medium. Through comparing the effects of different filtration media, it helps students to develop an understanding that matter is made up of particles of specific sizes and that different filtration media have different-sized holes.

The first part of this lesson is a comparison of five filtering media: sand and rock fragments, activated carbon, glass wool and two kinds of filter paper. It is more easily done as a teacher demonstration with the same polluted water sample as used by students. Using the same methods of evaporation and observation under a microscope as in the last lesson, compare the differences between the five samples of filtered water. Of the five filtration media used, the space between particles should be the smallest in the Lab Filter Paper and the biggest in the sand and rock fragments filter. Activated carbon is different from the other four media in that its main function is in absorbing dissolved coloured substances.

Before this lesson, the teacher needs to be equipped with suitable dirty water. There should be a trace of colouring which could be removed by the carbon, but there should also be colourless solutes present in the water, which can be identified through evaporation. Further, the solute in the water must not be harmful to the micro-organisms in the water otherwise the results in the other parts of the comparison will be affected.

After the demonstration, students should complete Section 1 of Worksheet W4A. It is important to discuss with students the results of the experiment and their implication. Students should have a clear understanding that besides the 3 main types of pollutants listed in the table in Section 1 of the worksheet, there are colourless pollutants which are soluble in water (colourless solutes). In the process of discussion, students may be prompted to suggest examples of such pollution e.g. sugar, table salt and other mineral salts.

The second part of the lesson deals with methods of killing germs. The teacher should set up 2 columns of micro-organism carrying water and treat the water using two different methods: UV radiation and chlorination. Ensure that you allow the set-up to stand for half an hour to allow the UV-radiation to take effect. Compare the effects of the 2 methods by observation under the microscope. If time permits, discuss the pros and cons of the 2 methods. (UV light treatment takes a long time and does not guarantee full eradication of all germs. However, it does not have side-effects harmful to man. Chlorine dissolves in water and can kill all germs if the amount used is sufficient. Unfortunately, an overdose of chlorine in the water can be lethal.)




The third section of this lesson (requires 1 to 2 periods in the laboratory) brings the focus more clearly on the size of particles. Here the students are going to perform group experiments to compare the effects of filtering on a variety of liquids. Using two different filtration media, filter paper and carbon, filter 3 different liquids: milk (white), ink (black) and grape juice (purple) and then evaporate the subsequent filtrates. The students are required to observe and record the effects of evaporating the filtrate in Section 3 of the worksheet. At the end of this experiment, students should have a better understanding of matter as composed of particles, the understanding that even when particles are not observable, matter are still composed of particles and that these can be of different sizes for different substances.

Finally, relate what seems to be laboratory procedures covered during the lesson to everyday applications. You can show a video on the different structures and effects of some commercial water filters on the market. Compare the designs and performance of these filters, and discuss the differences between these filters and those used in the laboratory. You may also take students to visit a swimming pool during chlorination, or show a video on the chlorination process. Maintaining hygenic standards in a swimming pool is another application of the purification of water apart from drinking. Distribute reference material W4C, a newspaper cutting on consequences of polluted swimming pools, to students as supplementary resource materials.

The following is a very good follow-up activity to this lesson that will require students to consolidate and internalize what they have learnt and to integrate the learning of scientific concepts and principles with the development of appropriate communication skills:

Show a video advertisement of a commercial water filter system. The class is then required to do group projects on designing commerical advertisements for an imaginary water-filter product as commissioned by the distributor of the product. Each group should:

1. Design a flyer describing the features and special advantages of the filter.
2. Design and perform a TV advertisement for the filter. It would be best if a video camera can be arranged to record the students' advertisements. The time allowed should not exceed 5 minutes per group.

This activity can also be organized as an intra-class or inter-class competition.

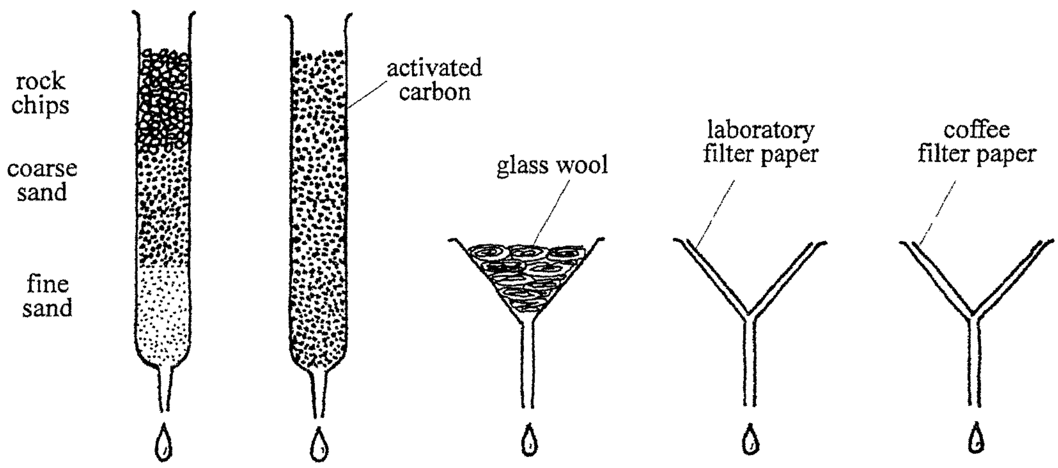
Date: ____________________

Name: ____________________

# W4A WHAT KIND OF FILTER DO WE WANT?

## 1. How are filters different from each other in terms of their function?

Record the results of filtering the dirty water provided using these five different types of filters.




Fine Particles

________ ________ ________ ________ ________

Colouring

________ ________ ________ ________ ________

Micro-organism

________ ________ ________ ________ ________

How does the performance of these filters differ from one another?

______________________________________________________________

Other than the three kinds of impurities listed above, are there any other impurities remaining in the water after filtration?

______________________________________________________________

## 2. How can bacteria be killed?

How can we kill the micro-organisms and bacteria that still remain in water after filtration so that it becomes safe to drink? There are two commonly used methods: radiation using ultra-violet light and addition of chlorine. How do these two methods differ?

| | Ultra-violet light | Chorine |
|---|---|---|
| Sterilization effect | ________________ <br> ________________ <br> ________________ | ________________ <br> ________________ <br> ________________ |
| Effect on the human body | ________________ <br> ________________ <br> ________________ | ________________ <br> ________________ <br> ________________ |

## 3. What are liquids composed of?

Try to filter separately milk, ink and red grape juice through filter paper and activated carbon. What components are removed from each of these liquids?

____________________________________________________

____________________________________________________

Why are the filtration results for these three liquids different? Does this have anything to do with their composition?

____________________________________________________

____________________________________________________

# Lesson 5 Boiled Water and Distilled Water

(Suggested time: 2 periods. This is a laboratory session)

This lesson still stays around the theme of purifying water, but endeavors at the same time to guide students to move closer to thinking about matter at the microscopic level through examining the differences between the processes of boiling and evaporation. By leading students to think about the changes that take place in water during these 2 processes, it is hoped that we can arouse students' interests in thinking about possible models of understanding the structure of matter, thus helping them to appreciate that such abstract ways of thinking is meaningful and fruitful. This will lay a good foundation for the next lesson

The pupils generally can comprehend that both distillation and boiling can kill germs because of the high temperatures involved. The first part of Worksheet W5A attempts to stimulate discussion on the relationship between boiling time, water temperature and the steam temperature by considering the problem 'Does boiling time affect the germ killing effectiveness of the process?'. Students should discuss in groups to decide on the measurements required to answer the question, and the appropriate set-up and procedures for conducting the investigation. The results of the discussion and the experiment should be recorded in Section 1 and 2 of the worksheet.

The section on drinking distilled water (Section 3 of the worksheet) brings students' attention to the fact that there may still be impurities even in purified water. They should understand that boiled water still contains impurities while distilled water is literally pure water. This discussion would also lay the foundation for exploring the differences between water and steam to be conducted in Lesson 7. As atomic structure and the kinetic theory are both abstract and hard to understand, these should not be introduced to students here. Stimulating an interest in using some form of a particulate model of matter in their thinking will be sufficient. If particular students are especially interested, they may be encouraged to pursue the topic further by reading resource references from the library and other sources. It may be possible to guide students to consider all kinds of possibilities for the structure of matter and to design experiments to explore their ideas further.

Finally, the teacher should demonstrate the distillation of water using the conventional laboratory set-up so that students may be introduced to the use of the Leibig Condenser for the distillation process.

Homework: This may be a convenient point to conduct a small scale test to check on students' progress and to put some pressure on students to consolidate what have been learnt so far in the topic. Worksheet W5B can be distributed as a kind of revision for the test.

Date. ____________________

Name: ____________________

# W5A BOILED WATER AND DISTILLED WATER

## 1. What are the advantages of using boiled water?

What impurities can boiling remove from water?

______________________________________________

What are the advantages of drinking boiled water?

______________________________________________

What effects would different lengths of boiling time have on sterilization?

______________________________________________

Would lengthening the boiling time increase the temperature of water?

______________________________________________

Can you design an experiment to find out the effect of boiling time on the temperature of water and the temperature of steam? What measurements are needed for this experiment?

______________________________________________

## 2. The relationship between boiling time, water temperature and steam temperature

Describe your experimental procedures and illustrate with a diagram.

Experimental Set-up

Experimental Procedures:

Experimental Results

| Time | Water Temp. | Steam Temp. |
|---|---|---|
| | | |
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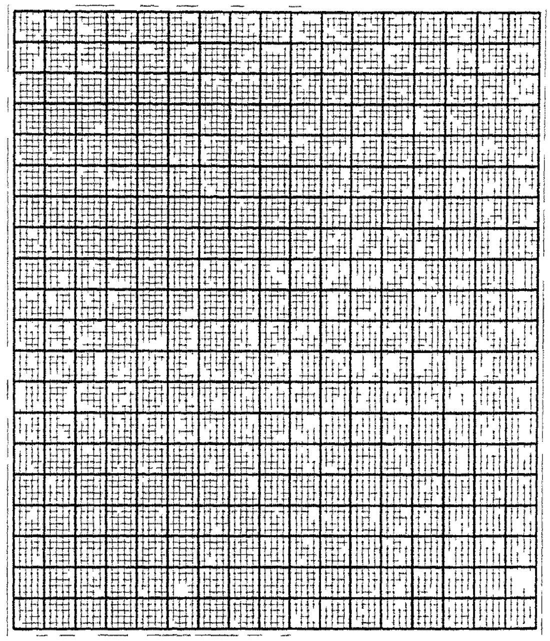


From results of the experiment, what is the effect of continuous heating on water temperature after the water has started to boil?

______________________________________________

What is the highest temperature that the water can reach?______________________

Steam is produced when water boils, Are there any changes in steam temperature when the water is heated after boiling has started? What is the highest temperature reached by the steam?

______________________________________________

## 3. Drinking distilled water

Does distilled water contain any impurities?

______________________________________________

What is the difference between distilled water and boiled water?

______________________________________________

Is the long term consumption of distilled water the best choice for our health?

______________________________________________

## 4. Water and Steam

Water when heated changes into steam. Steam changes back to water when cooled.

What is the difference between water and steam?

______________________________________________

What is water made up of? What is the effect of heating on its composition?

______________________________________________

Date: ____________________

Name: ____________________

## W5B FROM DIRTY WATER TO DRINKING WATER

**Section A Answer the following questions:**

1. What are the three main kinds of impurities commonly found in dirty water?

____________________________________________

____________________________________________

2. What methods can be used to remove these three kinds of impurities?

____________________________________________

____________________________________________

____________________________________________

____________________________________________

3. List one advantage and one disadvantage of using boiling as a method of water purification?

____________________________________________

____________________________________________

4. Which two changes does water go through in the process of distillation?

____________________________________________

____________________________________________

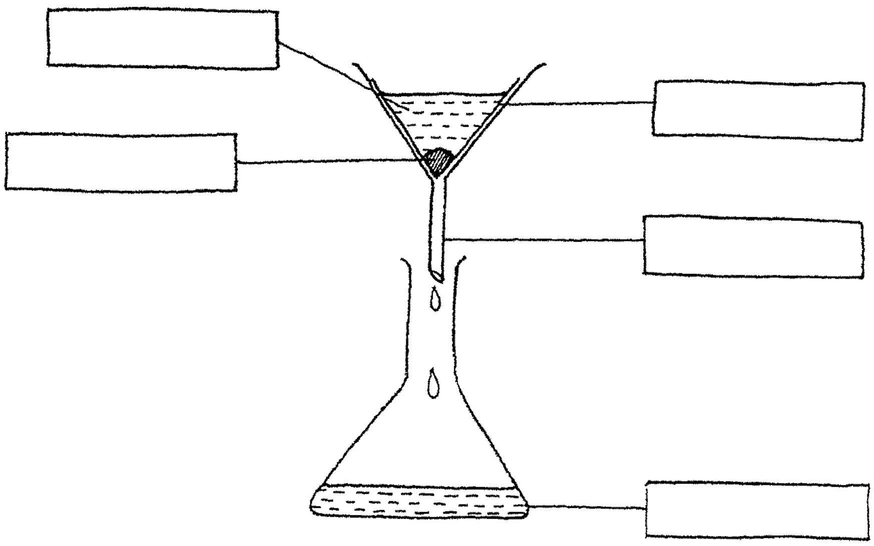
5. Why does Hong Kong use filtration and not distillation to purify its water supply so that it is fit to drink?

____________________________________________

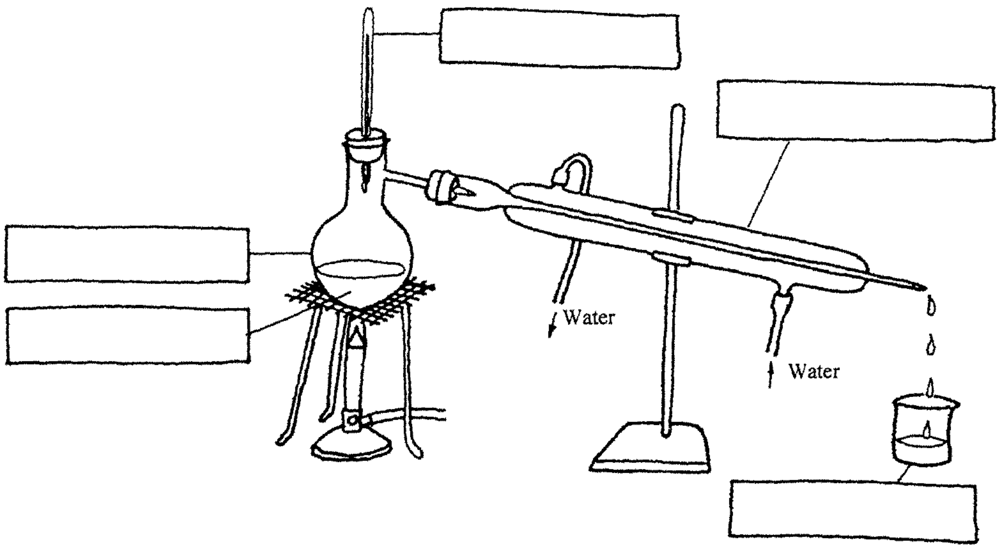
____________________________________________

**Section B Fill in the blanks in the following diagrams:**

1. Filtration



2. Distillation



# Lesson 6 Our Water Supply

(Suggested time: 2 periods)

This lesson focuses on how Hong Kong treats its water supply. It begins with examining the structure and function of the water treatment plant which is essentially a filter plant incorporating two further chemical treatments, chlorination and florination. It would be best if a visit to the Water Treatment Plant at Sha Tin can be arranged to fit in with the teaching schedule. Otherwise, this can be introduced using the ETV programme on this topic. The second part of the lesson introduces the already demolished desalination plant and has to be done again through the appropriate ETV programme.

This lesson aims to further the students' knowledge about one aspect of Hong Kong that relates to their everyday life, and to demonstrate that the industrial water purification processes are very similar to the laboratory methods they have already encountered in the module, with the main difference being only in the scale of operation. This lesson thus complements the preceding lessons very nicely and should heighten students' interests in science by demonstrating its technological relevance to our daily life.

In order to ensure active viewing of the ETV, the three worksheets designed for this lesson can be used as an exercise/mini-test for students. Students will be told to watch the video carefully so as to complete the worksheet which will be distributed immediately after the video show. Before distributing the worksheets, give students a chance to ask questions on any part of the programme that they don't understand. If time permits, it would be desirable to discuss the answers to the worksheets.

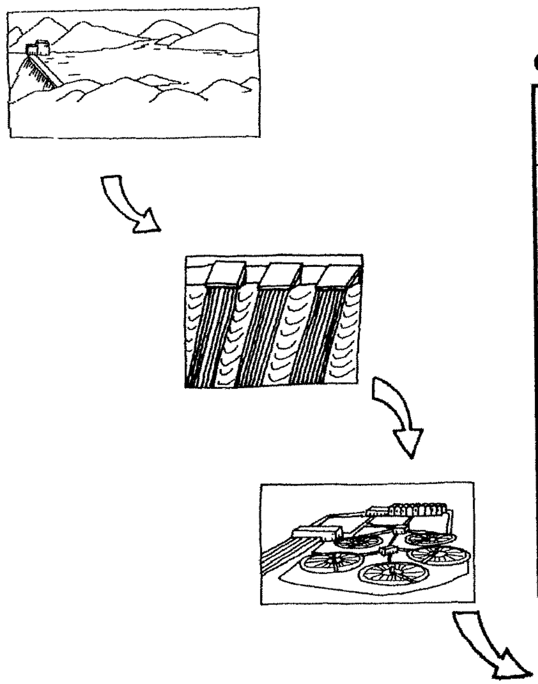
A suggestion for the lesson schedule is listed below:

| | **Activity** | **Time** |
|---|---|---|
| 1 | The teacher explains the answer to W6A (possibly with a transparency), and invite students to present their answers to the last 2 questions to the class. | 10 min. |
| 2 | Distribute worksheet W6B for students to complete as an introduction to desalination.. | 10 min. |
| 3 | Show the remainder of the programme 'Our Water Supply', including an introduction to the desalination plant. | 4 min. |
| 4 | Students complete worksheet W6C | 10 min. |
| 5 | The teacher explains answers to W6C and invite students to present their answers to question 2. | 10 min. |

Date: ____________

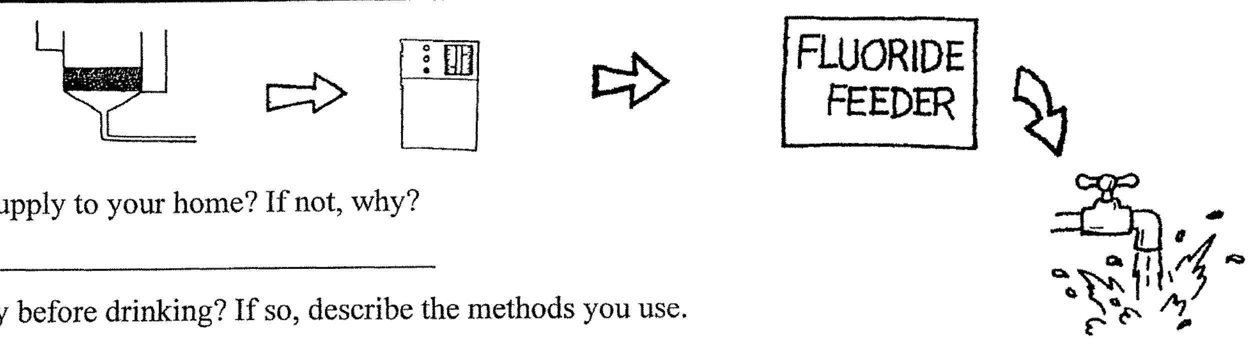
Name : ____________ Class: ____________

## W6A OUR WATER SUPPLY: the Water Treatment Plant



**Complete the following table on the water treatment procedures used in the filter plant:**

| Step | Process | Filter plant component | Effect on water quality | Treatment method |
|---|---|---|---|---|
| 1 | Coarse filtration | | | Pass water through the wire filter |
| 2 | | | Allow impurities to precipitate at bottom of filter bed. | |
| 3 | | | Remove insoluble impurities and small amounts of bacteria | |
| 4 | Sterilization | | | |
| 5 | Florination | Florinator | | |




Are you satisfied with the purity of the water supply to your home? If not, why?

______________________________________________

Does your family treat the tap water in any way before drinking? If so, describe the methods you use.

______________________________________________

Date: ____________________

Name : ____________________

## W6B OUR WATER SUPPLY: the Desalination Plant (I)

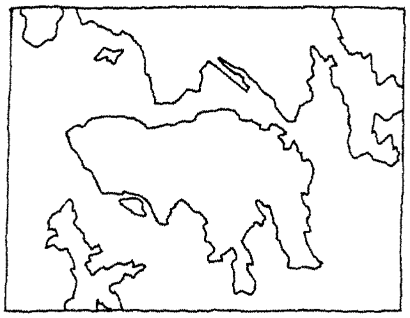
1. Hong Kong is an island, surrounded by water. Why is it that Hong Kong still needs to get part of its water supply from China? Why don't we use sea water as our water supply?

_______________________________________

_______________________________________

_______________________________________

_______________________________________



2. Suggest a way of making sea water fit for drinking.

_______________________________________

_______________________________________

_______________________________________

Date: ____________________

Name: ____________________

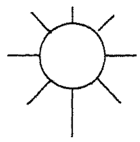
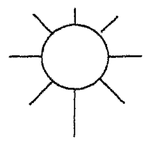
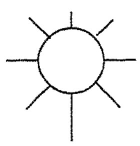
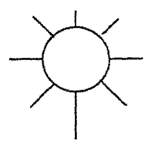
# W6C OUR WATER SUPPLY: the Desalination Plant (II)

1. Hong Kong had once built a desalination plant to meet part of the demand for water supply. Now Hong Kong depends only on ________________ and ________________ for its water supply.
2. Why did Hong Kong later sell the desalination plant?

   ______________________________________________________________

   ______________________________________________________________

3. In the ETV program, a model for desalinating sea water using solar energy was shown. Illustrate the desalination process by completing the diagram below.

| | |
|---|---|
| 1. Draw a simplified structure of the desalination plant above the pool of collected sea water.  SEA WATER | 2. When the sun comes out, what is the first change that takes place in the sea water?  SEA WATER |
| 3. When the sun has been shining for some time, what changes will be observed inside the desalination plant?  SEA WATER | 4. Show how the desalinated water is collected.  SEA WATER |

# Lesson 7 Artificial Rain

(Suggested time: 2 periods, preferably in the laboratory.)

This lesson provides a crucial link in the teaching sequence for this module. Up to this point, students would have done a lot of experiments on purification of water and should thus have accumulated quite a good knowledge of the kinds of impurities found in water and common methods of water purification. Through exploring the natural water cycle, students should become aware that the processes they have learnt about in this unit exist in similar form under a much bigger scale: that of macroscopic terrestrial weather conditions. This should stimulate in students a much stronger interest in Science. Furthermore, this lesson again targets the very important aim of guiding students to move towards thinking, imagining and exploring the question of "What is matter made of?" This is a very elementary question in science.

It is important to emphasize here that the aim of this lesson is not to provide students with an answer to this question, but is to stimulate students to move from thinking at the level of macroscopic, observable phenomena towards taking on a microscopic perspective.

The lesson should start with the problem: "Where does rain come from?" After some discussion, students should be introduced to the experiment 'Artificial Rain' and should perform the experiment in a group. Results should be recorded in worksheet W7A.

***Hints for the experiment***: To avoid the accumulation of tiny water droplets on the walls of the container* which would reduce the visibility of the resultant convection current prepare the container as follows: first pour detergent into the container, and then shake well in order for the walls of the container to have a layer of detergent on top, then pour away the detergent.

After the experiment, organize group discussion for students to consider the following questions and to present their views to the whole class.

1. Where did the water droplets at the bottom of the aluminium foil plate come from?

2. What can be found in the space between the water surface in the bottle and the aluminium foil plate?

3. What are the differences among water, steam and ice?

Homework: distribute worksheet W7B before the end of lesson 7.

* The plastic bottle can be easily made from a large soft drinks bottle (1.5 - 2 litre) by removing the top section from it.

Date: ____________________

Name: ____________________

## W7A ARTIFICIAL RAIN

**Why does it rain? Let us make rain in the laboratory.**

**What you need**: a clear plastic bottle, clear plastic wrap, ice cubes, small aluminium dish, a lamp, small pebbles, hot water (about 70°C) and food coloring (or some coloured drink).

**Steps you take:**

1. Warm up the small pebbles by soaking them in hot water for some time.

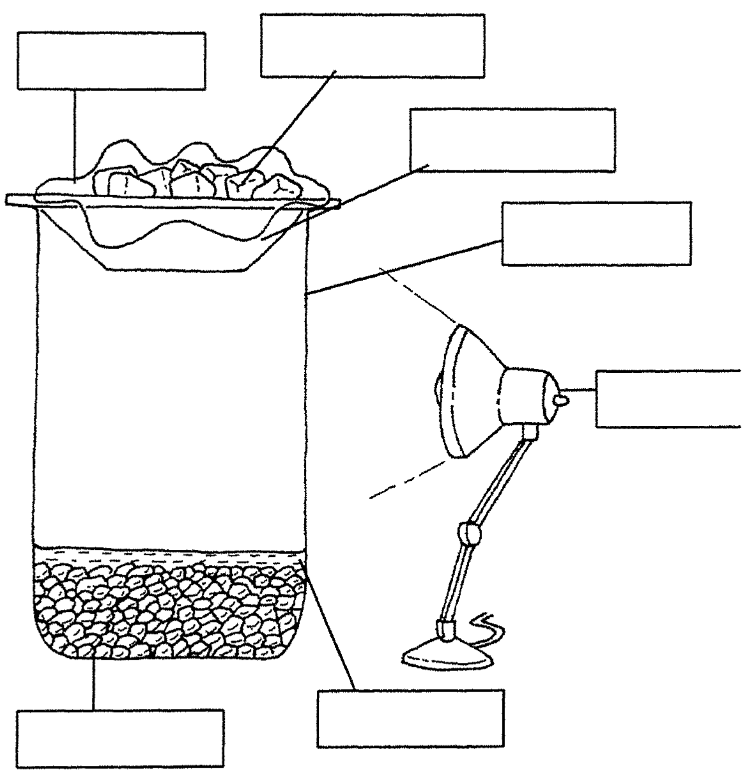
2. Remove the pebbles from the hot water and place them inside the clear plastic bottle. Pour in the hot water until it is 3 to 4 cm above the pebble surface.

3. Put in several drops of food colouring so that the water is visibly coloured.

4. Spread a clear plastic wrap on the bottom of the aluminium dish before placing the ice cubes inside the aluminium dish as shown in the diagram to ensure that no liquid will leak through the dish. Add in a little water. Place the dish carefully on the plastic bottle.

5. Place the lamp on one side of the set-up so that light is shining into the bottle from the side.

6. Observe what happens inside the bottle from a direction that is at right angles to the light beam.



**Observations:**

1. Observe carefully for 5 to 10 minutes and record your observations.

______________________________________________________________

______________________________________________________________

2. Is the water condensing on the bottom of the aluminium dish coloured? ____________

   Compare the condensation you observe and natural rain, name their similarities and differences.

______________________________________________________________

______________________________________________________________

3. Comparing this "artificial rain" set-up and the desalination plant, what are their similarities and differences.

______________________________________________________________

______________________________________________________________

Date: ____________

Name: ____________

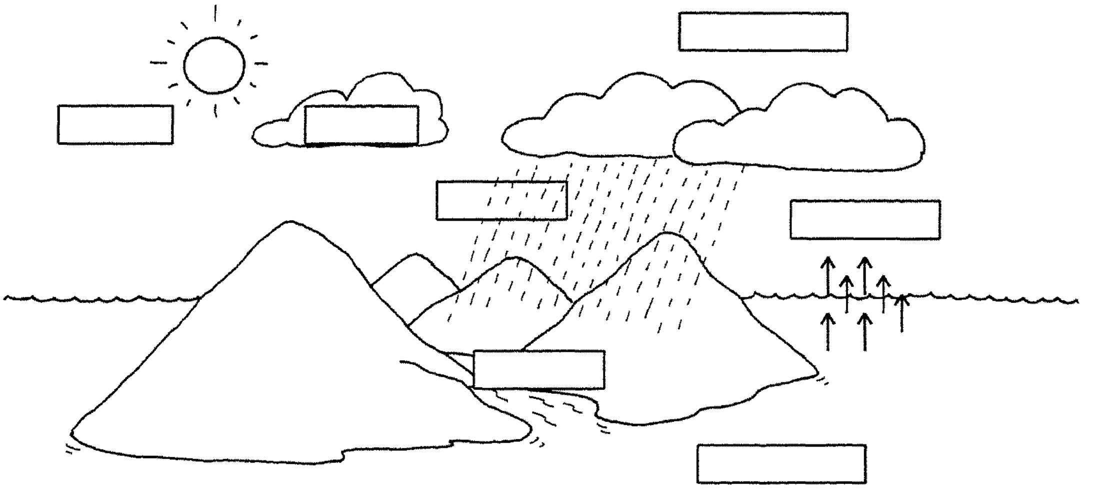
## W7B WATER CYCLE

1. Water evaporates continuously from the sea. Why doesn't it dry up?

_______________________________________________

_______________________________________________

2. Fill in the blanks in the following diagram using the following words: sea, river, sun, cloud, rain, evaporation, condensation.



3. Describe in words the complete cycle that water goes through as shown in the above diagram. Try to use all the 7 words from the above diagram.

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

# Lesson 8 Making Delicious Drinks

(Suggested Time: 2 periods, of which at least 1 in the laboratory)

Clean water is the basic component for all drinks. However, the drinks we enjoy most tend not to be pure water, but solutions. In the first part of this lesson, it is hoped that through making their own drinks, students would become interested in learning about solutions. Technical terms like solutions, solutes, solvents and concepts like solubility, rate of solution and factors affecting them can be introduced in a way that makes sense and has meaning in the context of everyday life. This also paves the way for exploring more formally the effects of parameters like temperature, amount of stirring and surface area of solutes on solubility and rate of solution in the latter part of the lesson.

Suggested drinks to make are: hot white tea, hot coffee, hot lemon tea, Pu-erh tea, iced white tea, iced coffee, iced lemon tea, orange drink, ovaltine, etc.

Materials to be provided are:

- instant coffee, breakfast tea bags, Pu-erh tea bags, orange powder, lemon drink tablets, ovaltine powder, evaporated milk, lemon slices
- glucose, white sugar, cubed sugar, rock sugar, sugar syrup
- boiling water, boiled water at room temperature, ice cubes

Students draw lots to decide on which drink each group is required to make (this ensures that the full range of drinks will be made by the class). Each group discusses and decides on the ingredients and method for making their selected drink. They complete the first part of worksheet W8A before proceeding to make the drinks. Students will be given the opportunity to try their own drinks as well as those made by other groups. Prepare paper cups for this experiment. It is expected that students will become very excited at this point, allow a few minutes for them to enjoy their drinks and chat.

After the drinking and clearing-up, ask each group to present briefly how they made their own drinks and whether they now wish to make any changes if they were to make it again. Other students are allowed to make comments and suggestions on improvement. All such suggestions have to be justified. During the discussion, guide them to think about questions such as:

- Why must we use boiling water to make white tea?
- Why don't we use rock sugar in making our drinks?
- Why doesn't sugar dissolve well in iced tea?

Such questions should be fun and yet are good problems in themselves, requiring a good understanding of dissolving and solutions in arriving at the answer.

Ask students to complete worksheets W8A and W8B as homework or classwork.

Another fun activity associated with this lesson is a 'Science Fiction Competition'. Worksheet W8C is the entry form. This is an attempt to encourage students to use their imagination to think about what happens at a microscopic level corresponding to macroscopically observable events like dissolving and evaporating. There is no right or wrong answer to this exercise and we wish to see students let go of their imagination as much as possible. During this process, teacher can find out more clearly how far students are able to move through this transition from macroscopic observations to taking on a microscopic perspective something that we have been working so hard to bring about. Furthermore, there are bound to be students who are more successful in making this transition and their works can then be used as source materials to discuss further with students. Such materials would be more appealing to students and more effective as teaching materials since these will be in a language and from a viewpoint that are meaningful and familiar to students.

The competition can be introduced at the end of the 'Making Drinks' session described above. The teacher should first briefly tell the story. (A student accidentally spilled some orange drinks on the table. He was not able to clean it up before leaving and returns to find that the spilt has dried up. This is a common phenomenon that is familiar to many students. Ask them to draw what a micro-organism will observe during the whole process.) The competition will be carried out on an individual basis and can be completed as classwork or homework. The teacher can then do a first screening to select 6 or so entries for posting in the classroom. Each student can then move round the room to view the entries and place their votes on the one that they like best. Their votes then determine which are the winning entries. The top 3 or 4 winners will tell their microscopic stories to the class. (The teacher may make a transparency for each of these entries to facilitate the story-telling process.)

Another very interesting extension to this lesson on solutions is to look at the problem of removing dirt from clothing or nail varnish from finger-nails. This is to extend students' understanding of solutions, to understand that all liquids can act as solvents and that different solvents will have different solubilities for different solutes. Cleaning agents can be seen as good solvents for the specific kinds of dirt for which they are good at cleaning.

The last part of this lesson is a set of practical exercise W8D on solubility and rate of solution for different solutes and different conditions. This is to formalize the concepts learnt in the 'making drinks' session and to introduce the technical terms involved.

Date: ____________________

Name: ____________________

**W8A**

## MAKING DELICIOUS DRINKS: ______________________________

(Write the name of your drink above this line )

Draw in the box below the drink you are going to make:

***Ingredients needed***:

______________________________

______________________________

______________________________

______________________________

______________________________

***Steps in making the drink***:

______________________________

______________________________

______________________________

______________________________

______________________________

______________________________

______________________________

***Satisfaction***: Are you satisfied with the drink you made? Would you like to suggest changes to your method of preparation described above?

______________________________

______________________________

______________________________

***Key to success***: What are the most important things to remember in terms of either choice of ingredients or particular steps in preparation for making your drink successfully? What are the common mistakes in making this drink?

______________________________

______________________________

______________________________

______________________________

Date: ____________________

Name: ____________________

# W8B FROM DRINKS TO SOLVENTS & SOLUTIONS

What are drinks?

The main ingredient of all drinks is water. Generally, drinks are made by mixing other ingredients with water.

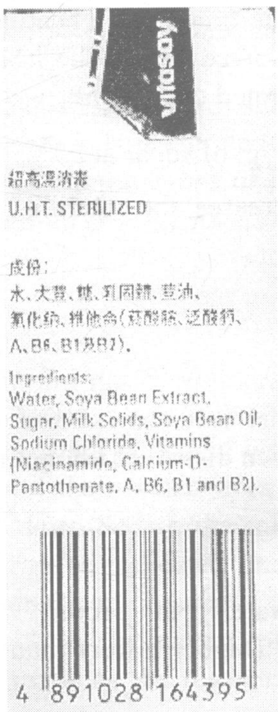
Therefore, drinks are composed of water and substances that dissolve in water.

We call anything dissolved in water a **solute**. Instant coffee powder and sugar are examples of solutes.

A drink can itself be called a **solution**. Coffee, tea and soft drinks are examples of solutions.

Anything used to dissolve solutes is called a **solvent**. Water is the most common solvent used in making drinks.

Can you name the solutes, solvents and solutions in the two boxed drinks shown below





Solute(s): ____________________  Solute(s): ____________________

Solvent(s): ____________________  Solvent(s): ____________________

Solvent: ____________________  Solvent: ____________________

Date: ____________________

Name: ____________________

# W8C TECHNIQUES IN MAKING DRINKS: explorations in solubility and rate of solution

**A. Solubility**

Fill a beaker with 100 ml of water. Put a teaspoonful of sugar into the beaker and stir until all the sugar is dissolved. Repeat until no more sugar can be dissolved under room temperature. Can you find out how much sugar has been dissolved altogether?

**Observation**: 100 ml of water dissolved _________g. of sugar under room temperature.

The amount of solute that can be dissolved in 1 litre of the solvent is called the **solubility** of the solute in the solvent. The unit for solubility should be _________
Therefore, the solubility of sugar in water is __________________________.

The sugar solution you now have is called a **saturated solution** because it is holding the maximum amount of sugar it can possibly dissolve.

**B. Relating solubility and temperature**

Heat the sugar solution you just made, stirring all the time during heating, until it reaches 50°C. What happened to the sugar that was undissolved before the heating? How much more sugar do you need to make the solution a saturated one again?

**Observation**: 100 ml of water dissolved _________g. of sugar at 50°C.

Therefore, when the temperature of the solution increases, the solubility of sugar in water

__________________________.

**C. Solubility of different solutes**

Fill another beaker with 100 ml of water. Put a teaspoonful of salt into the beaker and stir until all the salt is dissolved. Repeat until no more salt can be dissolved under room temperature. Can you find out how much salt has been dissolved altogether?

**Observation**: 100 ml of water dissolved ________________ salt under room temperature.

Therefore, the solubility of salt in water at room temperature is ____________________, and is thus _________ (higher/lower) than the solubility of sugar.

**D. Rate of solution**

We always stir our drinks after adding in sugar. Why?
Stirring can help to make the dissolving action happen faster: in other words, stirring can increase the rate of solution.
Can you name some other ways of increasing the rate of solution?

1. ______________________________________________

2. ______________________________________________

# Lesson 9 Fascinating Crystals

(Suggested time: 4 periods, at least 2 in lab)

This is the last lesson in this module. Until lesson 8, attention was focussed all the time on water and getting rid of the impurities in water. In the last lesson, the task has shifted to putting solutes (which can be seen as some kind of desirable impurity) intentionally into water. In this lesson, we also work with solutions, but the focus is NOT on water, but on getting the solute back from the solution. So this is again a process of purification, but the desired extract is now the solid component.

There are two parts to this lesson. To start with, students will be shown actual specimens of crytals, naturally occurring ones as well as those prepared in the laboratory. Students would be fascinated by the beautiful shapes of crystals of common substances. The teacher can then ask students if they would like to grow their own crystals. In so doing, the teacher can show samples of particularly big and well formed specimens, including big crystals of copper sulphate. The response will definitely be a resounding "yes". The teacher can then show them a video or perform a demonstration on how to grow crystals before allowing them to do so in the laboratory. Some teachers may like to organize the crystal growing as a competition where students will buy their own materials and grow them at home. Worksheet W9A can be distributed to be completed by students either as classwork or homework.

The second part of this lesson takes students to look at crystal growing under the microscope. The teacher can prepare concentrated solutions of several substances, e.g. copper sulphate, table salt, sugar etc. and put drops of them on watch glasses so that they can evaporate very quickly, leaving visible powder forms of the solute. The teacher can pass these watch glasses around and ask students if these powder forms are also crystals. These look so different from the big crystals and does not appear to have a particular structure. Let students discuss briefly whether they think these are still crystals, get them to present their views and justifications for why they make such conjectures. After their views are expressed, ask students how they might verify their views. Hopefully some students will suggest using a microscope. We can guide them to think about watching crystals grow under the microscope. They have observed crystal growing with their naked eyes and they can only discern the growth by comparison over a number of days. Set up the microscope (the best would be a projection microscope where the image can be projected onto a TV screen) and let students observe a variety of crystals grow under the microscope. They will be fascinated to find that ALL THE TIME, from a minute speck on the screen, each solid particle separating out from the solution has exactly the same shape as the big specimens of the same substance they have seen before.

The teacher can have specimens of large crystals of these substances around and show to the class while watching the same substance grow under the microscope. An important aim here is to get students fascinated, get them to wonder why things should behave so. After the demonstration, get students to talk about what they think and how they feel.

- Why do crystals of different substances have different shapes?
- Why do crystals of the same substance always have the same shape?
- What can we deduce about the substances themselves from such observations?
- What would we be able to see if we can have ways to look at crystal growing at a much smaller scale (Imagine you have a microscope 1000 times more powerful than the one being used.)?

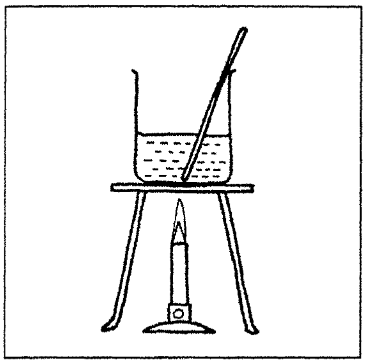
If students can share these questions, or even better, ask these questions themselves, we would have accomplished the implicit aim of this module: getting students to move towards thinking about matter at a microscopic scale. Do not hasten to answer these questions. Put them in suspense. Praise them for asking these questions, tell them that these are wonderful, big questions that scientists of all ages have been fascinated by and these do not have simple answers. Tell them that in the next module, we will exactly be exploring what matter is like if we can see them through powerful microscopic eyes. Distribute worksheet W9B for students to complete as classwork. Do not give students any hints. Tell them not to worry and that you only want to know their views. Answers to this worksheet is very useful to the teacher in terms of understanding where students are in terms of their depth of understanding of what crystal growth is. The best way to go over this worksheet with students is not to give them a model answer, as a model answer does not really help students at all if they cannot attain the same conceptual understanding required for the answer. Instead, go through the students' responses and pick out several different responses (you may be surprised to find how sophisticated some of these are) and let them discuss what they think of such responses. The students' answers offer progressive ways of understanding microscopic structure and behaviour in students' own language. Discussing in such a way encourages students to value and take pride in their own independent attempts to think and to share their thinking. This also makes abstract thinking and model building in science much more accessible to students and builds up their interest and confidence in learning science.

Date: ____________________

Name: ____________________

## W9A GROWING CRYSTALS

Crystal growing is simple and comprises 4 main steps. Complete the following to show the main steps in growing good, big crystals.

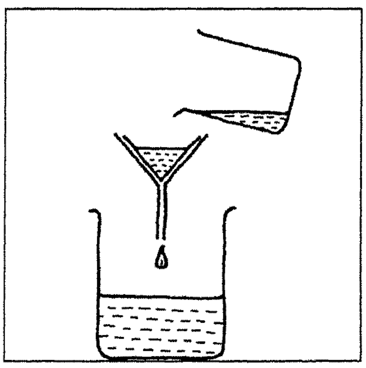


1. ________________________________________________

________________________________________________

________________________________________________

________________________________________________

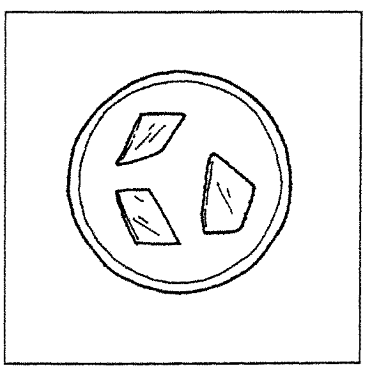


2. ________________________________________________

________________________________________________

________________________________________________

________________________________________________

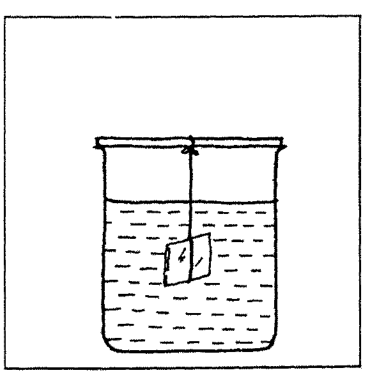


3. ________________________________________________

________________________________________________

________________________________________________

________________________________________________



4. ________________________________________________

________________________________________________

________________________________________________

________________________________________________

Date: ____________________

Name: ____________________

## W9B WONDERFUL CRYSTALS

1. Crystals of the same substance, whatever their sizes, have the same shape.

   Why is this so?

   ______________________________________________

   ______________________________________________

   ______________________________________________

   ______________________________________________

2. During the process of crystallization, a crystal will grow bigger and bigger. Plants also grow bigger under suitable conditions.

   What are the similarities and differences between these two kinds of growth?

   ______________________________________________

   ______________________________________________

   ______________________________________________

   ______________________________________________

# The Structure of Matter

## Suggested teaching guide for the unit on "MATTER"

This is a very exciting and challenging unit to teach. On the one hand, this unit introduces the idea that all matter is made up of particles, and from this a first introduction to atomic theory, the theoretical basis on which the whole of modern Chemistry is based. On the other hand, atomic theory is extremely abstract, and cannot be simply derived from experimental results. It is typical of all important theories in science: it is a product of a long process of man's exploration of the wonders of the natural world, beginning with a rich, creative imagination, supported by numerous experimental clues and logical deductions. In order that students can appreciate the nature and importance of this theory, simple memory of terms and information is vastly inadequate. We must stimulate their interest, their curiosity and sense of wonder. They must feel that the problem of the microscopic structure of matter is a mysterious one and yet related to the wide range of everyday phenomena in important ways.

The concept of looking at matter from a microscopic perspective has already been introduced in the previous module, "Can Dirty Water Become a Delicious Drink?". Students have observed micro-organisms through the microscope. They have seen the fascinating regular growth and arrangement of matter that are too small to be seen even through the microscope. They have also written science fictions about the world as seen through the eyes of a micro-organism. This module capitalizes on these favorable prior experiences and continues to stimulate and build on their interest and curiosity about the microscopic world.

The focus of this module is on atomic theory. This aim cannot be achieved simply through direct personal experience of students nor through simple induction. There is a need to help students to understand what scientific models are and the nature of theoretical explorations in science. Thus the suggested approach for this module is different from the earlier one. It starts with stimulating curiosity and conjectures, and through introducing various theories about the structure of matter that existed through the ages, guide students to understand that scientific theories are fundamentally subjective creations of the human mind, not facts or truths. This module also tries to help students to understand the implications and importance of theoretical models on scientific development.

The second part of this module presents some experiments that are designed to highlight some features of the fundamental constituents of matter through direct experiences. This enhances the credibility of the atomic theory and help students to recognize some of the phenomena that this model may help us to understand. Note: The purpose of these experiments is NOT for providing data that may lead to the atomic theory being derived or induced from.

## Lesson 1 The mysterious world of matter: man's incessant explorations of nature

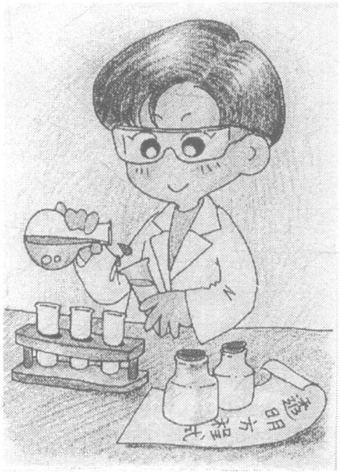
Start the module with the story of the invisible man (reference material M1A), stimulate students to think about and explore things that cannot be detected by our naked eyes. Then, the teacher can ask the fundamental question of what makes up matter and how this question may be explored.

After some discussions, the teacher can distribute the reference material "Story of atomic theory"(reference material M 1B), and also allow students time to read carefully and discuss.

## M1A

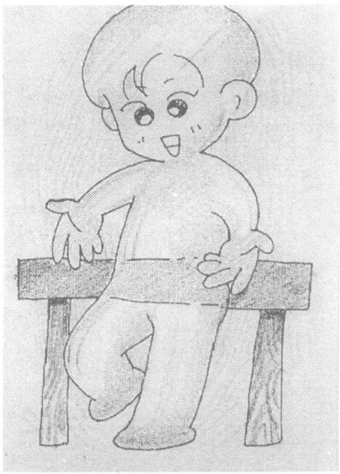
## The Invisible Man

Have you heard of the book “The Invisible Man” written by H. G. Wells? It is an extremely interesting story. Let’s read the outline of this story.

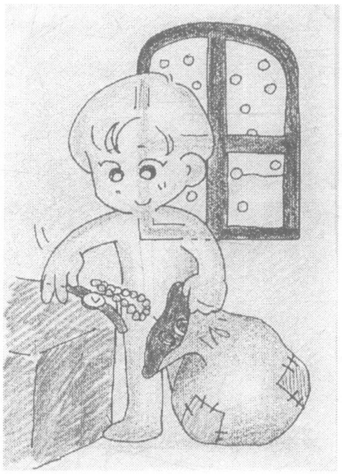



Once there was a young chemist who succeeded in making himself invisible.

At first, he was very happy and very proud of his achievement.

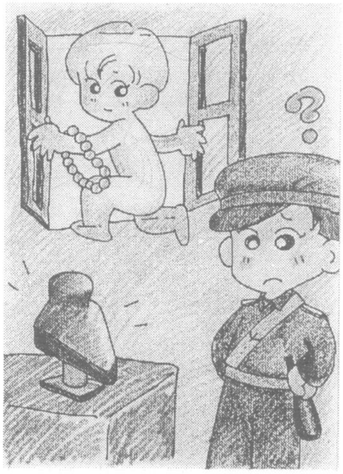


However, he soon found that he could not make himself visible again. All of a sudden, his success became an intolerable burden.



Having become invisible, he could not live a normal life. He was forced to commit crimes and the police had a hard time trying to catch him.

Alas, how can one find an invisible criminal? This "chemist" would sometimes open a window or a door to show that he was still around, but nobody could see him




His numerous crimes had made him the most hated enemy of the people. Many times, the police organized massive searches for him, even using huge nets in the fields in order to catch him. All these efforts failed.

One day, an uninvited guest gave the police a big help. It began to snow. Just around where the chemist had committed a crime, a row of footprints appeared on the snow and pushed forward very quickly in front of people's eyes. The police shot at the furthest footprint, and more footprints appeared. The police shot again at the furthest footprint that newly appeared.

Suddenly, there appeared a hollow in the shape of a man on the snow. Soon, this hollow became filled with some hazy, transparent matter which slowly took on a clearer and clearer image until people discovered that the body in front of them was the chemist's. It was only till death that he could be seen by others again.

We may not have met the invisible man. However, we are surrounded by things and events that we cannot see with our naked eyes. Can we find ways to expose signs that can help us to study their characteristics?

## M1B Story of the Atom

Of the myriad materials in the world around us, what are they made of? Is there anything common between different kinds of matter? Human beings have long been fascinated by questions like this. Different views about the composition of matter have been recorded from as early as more than two thousand years ago. Have you heard of the term "ATOM"? "Atom" is the name given to the particles that make up all matter. The reason why "atom" is such a famous word is because after thousands of years of exploration, most people have accepted the atomic theory (the theory that all matter is made of particles) as the best answer to the question of "What makes up matter?"

The history of the atomic theory should start with the Greeks.

The earliest record on man's thinking about the structure of matter dates back to about two thousand four hundred years ago. It recorded the belief of Zeno, a man from Elea in ancient Greece, that any matter can theoretically be cut into an infinite number of pieces.

**The First Atomic Theory**

Then around 420 BC, another Greek philosopher, Democritus, disagreed with this view. In thinking about the problem of why different materials have different densities, he arrived at the conclusion that matter is made up of many 'small pieces'. The 'small pieces', he said, were invisible, indivisible, could not be pierced through or reshaped, and could not be changed into other kinds of particles. He said that in the universe, there were only atoms and vacuum, everything else were illusions. Unfortunately, with no experiments to support it, the Atomic Theory remained just a brilliant idea.

Actually, the idea of using experiments to find out whether a viewpoint is believable is a fairly modern one. Even the famous philosopher Plato believed that only thinking is important, experiments are a waste of time. Information gathered through the five senses was considered to be unreliable, and may even be illusions. Logical deductive thinking was considered to be the only reliable research method and this belief remained influential until about 400 years ago.

**Theory of the elements**

Democritus's theory of atoms was not generally accepted by the people around his time. One of his students, Aristotle, who became much more famous than he, was against this atomic theory of matter. He believed that all matter is made up of different combinations of four elements: earth, water, air and fire. These four elements are in turn derived from dryness, wetness, heat and cold. For example, wood produces heat when it burns, leaving behind ash. People then believe that wood (dryness) is composed of earth (ash) and fire.

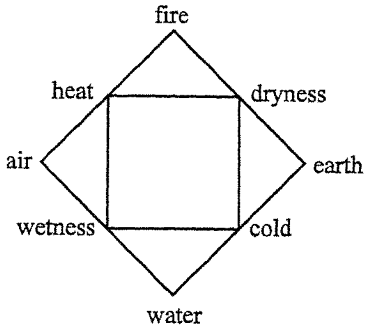



Fig. 1. The elements chart of the Ancient Greeks

**The Chinese Five Elements Theory**

In ancient China, people believed in a similar theory, that is, the "Five Elements" theory. The five elements refer to the five most common kinds of materials people meet in their everyday life: wood, fire, earth, gold and water. Ancient people found that these five kinds of materials can be made into many different kinds of new materials when combined in different proportions and processed in various ways. Thus people came to believe that these five kinds of materials are the most fundamental materials of all matter in the universe. More than two thousand years ago, in the period of West Zhou, there were already records of the belief that "all matter is derived from combinations of earth with gold, wood, water and fire". Later, this belief evolved into the theory of the five elements. According to this theory, the five elements are inter-related to each other so that for each pair of elements, one element would be either supportive or destructive of the other. Further, one element can be transformed into another.

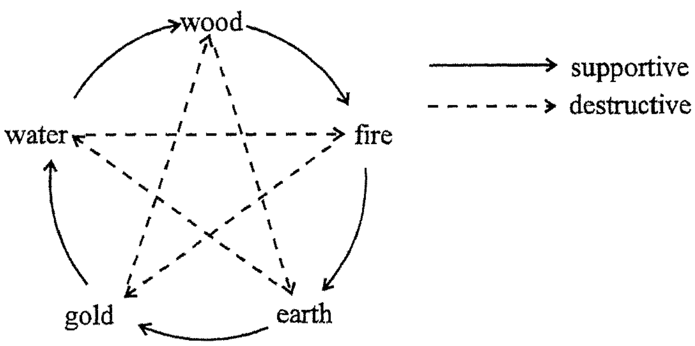



Fig. 2 Diagram showing the interrelationships between the five elements.

In the end, the five elements theory developed into a classification method as well as a theory of deducing the relationships and trends of development between things and events.

**The Rise and Fall of Alchemistry**

For a long time, under the influence of the elements theory of matter, people believed that one should be able to find ways of making any kind of material from a combination of others. For example, one should be able to make gold from much cheaper materials. Do not think that such beliefs are just ideas and thus unimportant. Sometimes, ideas can have extremely serious consequences. Because many people believed that gold could be prepared from other substances, and such a belief had dominated all thinking and explorations involving matter and materials. Basing their faith on the elements theory, many people in both China and the West became alchemists (people whose work was to find ways to turn cheaper materials into gold). In China, some people even believed that the alchemists' gold was more precious than natural gold because it was considered to be the essential ingredient of "gold potions" which would bring longevity to those who take them.

The study of alchemistry led to the establishment of the metallurgical industry and during this process a lot of information about materials and their properties became known. However, all these efforts over several hundred years failed to achieve their goal. People began to doubt the theory that any matter can be transformed from other materials. The first person to publicly oppose the four elements theory was the Irish scientist, Robert Boyle (1627-1691). He pointed out that gold will not be changed even when one uses fire to heat it: it will not be disintegrated by fire, nor will it produce other matter under the effect of fire. Therefore, he argued that the alchemists' efforts were unsound even from a theoretical perspective. Though even without the support of experimental results, he was a believer of Democritus's atomic theory.

It was also about that time that people started to pay attention to experimental investigations results. Both Boyle and Newton believed that in order to find out which theory is the right one about the structure of matter, one must complete the following tasks:

1. Study the properties of matter
2. Use experimental results to verify the ideas
3. Create a theory to explain them.

Such views are very different from the Greek tradition of using logical deduction which requires no reference to what happens in reality.

**Modern Atomic Theory**

From the 17th century till now, man has been trying to find out the secrets of the material world. The publication of the book "Atomic Theory" by Dalton in 1808 can be considered as a milestone in this exploration. Based on some experimental data and some trends generalized from the data, Dalton proposed a more comprehensive atomic theory. It can be said that Dalton established the foundation of modern atomic theory.

The history of man's guesses and explorations on the structure of matter is very interesting and illuminating. Are you interested in knowing more about the story of the atom?

**Lesson Two Challenging the World of Matter - the Alchemists' Quest**

During this session, the teacher can demonstrate two chemical experiments both of which will change something into "gold". The first experiment uses town gas to reduce black copper oxide, leaving reddish gold copper pellets. The second experiment first changes a piece of reddish gold copper strip into a "silver" strip, and through a second process into a shiny "gold" strip.

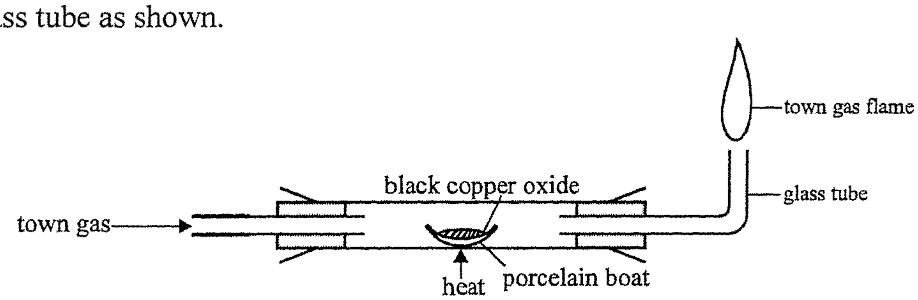
It is hoped that through these two experiments, students can have some experience of the fascinating world of chemical changes. It also gives them some understanding of why so many people in the past have worked so hard in alchemistry, to the extent of labouring on the same problem for several hundred years. This lesson would be a great help to them in understanding and taking interest in the resource material distributed to them in the previous lesson "Story of the Atom". In giving them some historical background to the study of the atom, students may find it easier to appreciate the significance of the discovery that the alchemical dream is not to be realizable. The destruction of this dream marked a big step forward in man's understanding of the material world. At this point, the teacher may wish to introduce a little bit of the modern idea of elements and evolution of the concept of an atom.

Details of the demonstration experiments are as follows:

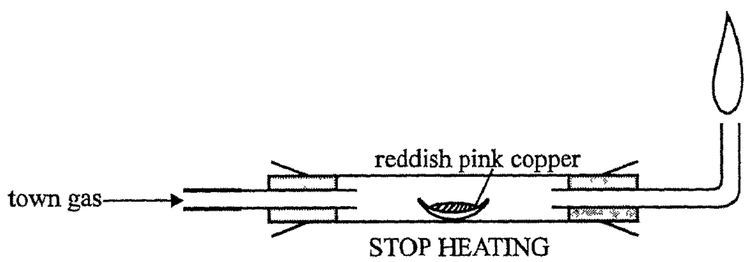
**Experiment. 1 Reduction of black copper oxide to "gold" (copper)**

Procedure:

1. Put some black copper oxide onto a porcelain boat and place the boat inside a combustion tube.
2. Pass town gas into the combustion tube for a few seconds and then light the town gas at the glass tube as shown.




3. Heat the black copper oxide strongly until it is reduced to reddish pink copper.
4. Allow the copper to cool down. Continue to pass town gas until the copper is cooled.




5. Turn off the town gas supply and take the copper out of the combustion tube.

**Experiment. 2 Turning a piece of copper into "silver" and then "gold"**

Procedure:

1. First place about 5 g of zinc powder in an evaporating dish. Add enough 6M sodium hydroxide to cover the zinc and fill the dish to about one third full.
   **Be careful with the sodium hydroxide as it is very corrosive.**

2. Heat the dish carefully until the solution is near to boiling. A solution of sodium zincate is formed.
   **Be careful with the hot solution as it is very corrosive.**

3. Put a copper coin, e.g. a twenty-cent-coin or a fifty-cent-coin into the hot mixture in the dish using a pair of tongs. The copper coin will turn "silver". This is because copper is displaced by zinc.

4. Remove the coin carefully with tongs, rinse it with water and dry it with filter paper. Carefully put the "silver" coin on a hot plate. The coin will turn into "gold". This is because the zinc and copper form an alloy - brass at the surface.

## Lesson 3 Exploring the structure of matter and characteristics of the particles that make up matter

Here is a set of experiments that aims at guiding students to think and explore further some characteristics relating to the structure of matter. The titles of these worksheets (M3) indicates how the thinking about such problems may proceed.

1. Even though I can't see them, I still know that they are there!
2. The particles of matter will not disappear!
3. There's enormous amounts of space between particles
4. Are particles making up different kinds of matter of the same size?
5. Those particles are more restless than the most hyperactive child - they never stop moving!
6. The particle movements are disordered 'random movement'
7. The speed of the particles' random motion increases with temperature

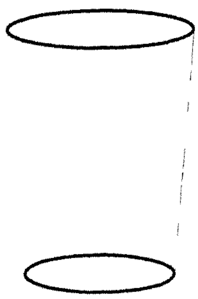
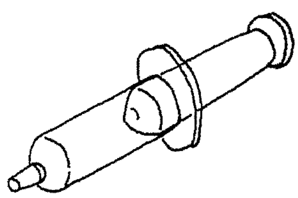
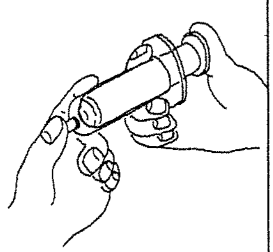
During the development of this theme, the teacher may wish to add in other experiments and other reading materials for students to help them understand the difficult and abstract theory of the atomic structure of matter, the theory that is the foundation stone of modern Chemistry.

# What is Matter Made Of?

About 2000 years ago, some philosophers hypothesized that all matter is made of particles. They believed that all matter, including humans and all other living things, are made of numerous, extremely tiny, indivisible particles. They called these particles 'atoms'. They also believed that enormous amounts of space exist between particles, and that these particles are continuously in motion. These hypotheses are very advanced even today. Unfortunately, they failed to prove the existence of these particles or their characteristics experimentally.

Even if particles existed, we cannot see them. Can we find any clues for the existence of atoms?

**1. Even though I can't see them, I still know that they are there!**

| | | |
|---|---|---|
| Expt. 1 |  | Is this cup really empty?<br>Can you prove that it is full of matter inside? (You can use a diagram to show how your method works.)<br><br>Do you know what kind of matter that is?<br>______________________ |
| Expt. 2 | <br> | Pull the syringe's piston back.<br>Now, the syringe is filled with ________.<br><br>Use your finger to close the syringe's air-hole tightly and use your other hand to push the piston down. What do you feel?<br>______________________<br>______________________<br><br>If you keep the air-hole closed, can you press the piston down completely?<br>______________________<br>______________________<br>______________________<br><br>Why is it like this?<br>______________________<br>______________________ |

## 2. The particles of matter will not disappear!

The world of matter is diverse and continuously changing. Sometimes, it causes confusion; sometimes, it is hard to understand. Often, matter seems to disappear right before our eyes. For example, sugar will disappear very quickly when mixed with water. If a glass of water is left standing on the window ledge, much of it will have disappeared before long. If matter is made of particles, then, when matter 'disappears' before our eyes, do the particles still exist? What do you think?

a. Sugar disappears very quickly when mixed with water. Can you prove that the sugar particles are still there and not gone?

______________________________

______________________________

______________________________

b. When a glass of water is placed on the window ledge, much of the water will disappear soon after. Where have the water particles gone? Can you prove where they have travelled to?

______________________________

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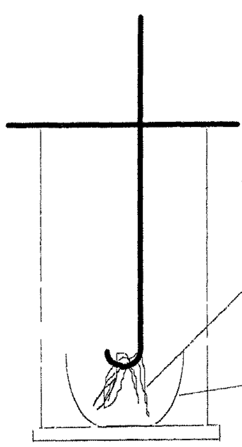
c. When an object is burnt, it appears to be eaten up by the flames; and when burning stops, all matter seems to have disappeared. Does burning really destroy the particles?
Let's perform an experiment.




This is an experiment to investigate the change of weight during burning.

Steps:

1. Weigh a few strips of magnesium using an electronic balance.
   The weight of the magnesium strips is ______.
2. Hang the magnesium onto a metal spoon, and then put it into a gas jar with a small heat-resistant ceramic bowl in it. Measure and record the weight of the whole apparatus.
   The total weight before burning is ________.

   Total weight of equipment (excluding the magnesium strips)
3. Take the spoon and the magnesium together to a lighted Bunsen burner, ignite the magnesium, then put it back into the gas jar as shown in the diagram. After burning is completed, weigh the whole set-up.
   The total weight after burning is ________.

From the results above, the weight of the magnesium after burning is____________.

Why are the results like this? What does burning do to the magnesium?

__________________________________________________

### 3. There's enormous amounts of space between particles

When we look at a dense forest from afar, it looks like a solid barrier. But, when we observe closely, we find that among the leaves and trees, there is enormous amounts of space.

We often meet materials that do not seem to allow anything through. In reality, is there any space among the particles that make up matter? Let's explore this by doing a few experiments.

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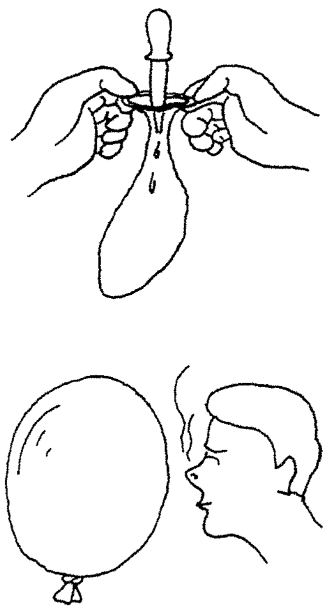
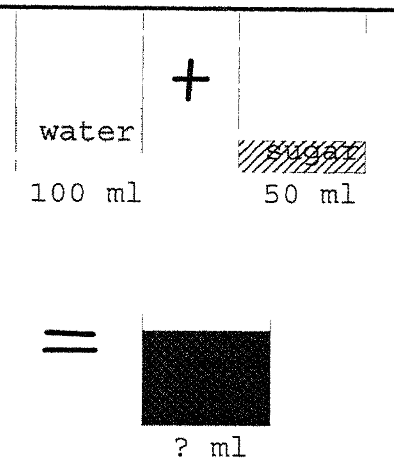
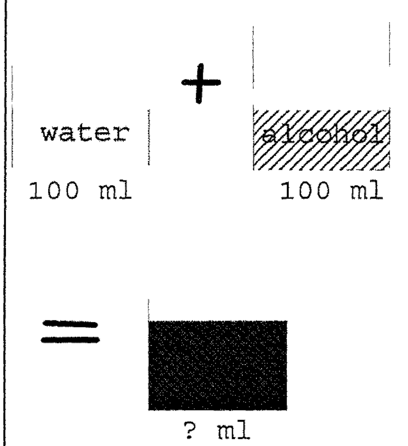
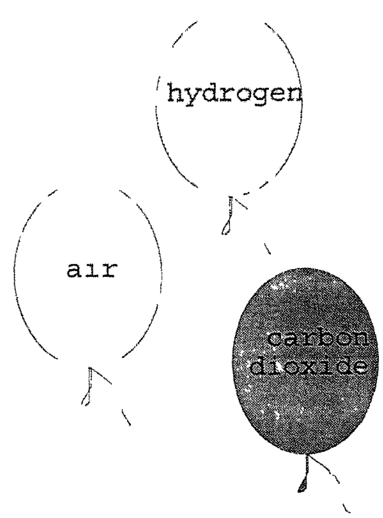
|---|---|---|
| Expt. 1 |  | Inflate a balloon slightly and, using a dropper, carefully put a few drops of flavouring (e. g. vanilla flavouring) into the balloon. Here, it is vital that none of the flavouring gets dropped near the opening of the balloon.<br><br>Then, inflate the balloon to the normal size and tie up the opening tightly. Shake the balloon gently for a few seconds and put the balloon near to your nose. Can you smell anything?<br><br>________________________<br>________________________<br><br>What can this observation tell us? What connection does this have with the particle theory?<br><br>________________________<br>________________________ |

| | | |
|---|---|---|
| Expt. 2 |   | Mix 100 ml of water with 50 ml of sugar. When the sugar is completely dissolved, what is the total volume of the solution?<br><br>What is the difference between the volume of the solution and that of the total volume of the 2 separate components before mixing? Can you explain the difference between them using the particle theory? |
| Expt. 3 |   | Mix 100 ml of water with 100 ml of alcohol together. What is the total volume of the mixture?<br><br>What is the difference between the total volume of liquids before and after mixing? Why is it like this? |

**4. Are particles making up different kinds of matter of the same size?**




Have you noticed that a fully blown balloon would become smaller with time? Do you know why this happens?

Using hydrogen, carbon dioxide and air, fill the balloons up to the same volume. After labeling on each balloon the gas inside, leave them somewhere in the lab. After a couple of days, check what has happened to the balloons.

What changes have taken place? What is the difference between the 3 balloons?

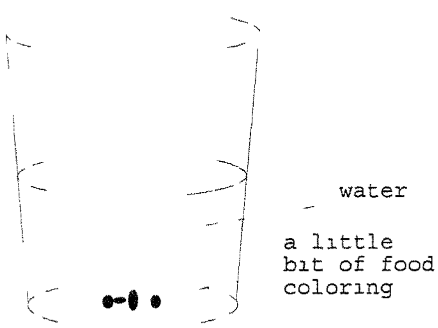
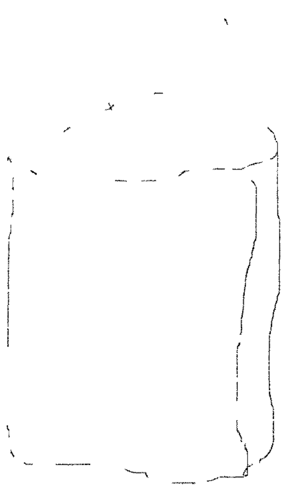
Can you explain why there are such differences among the 3 balloons?

______________________________________________________________________

______________________________________________________________________

**5. Those particles are more restless than the most hyperactive child - they NEVER stop moving!**

Have you ever considered why it is that you could smell the food cooking in the kitchen from a long distance away? This is because some of the smell-bearing particles that escape from the food roam about in air and reach our very sensitive smell sensor (the nose) and are detected by it.

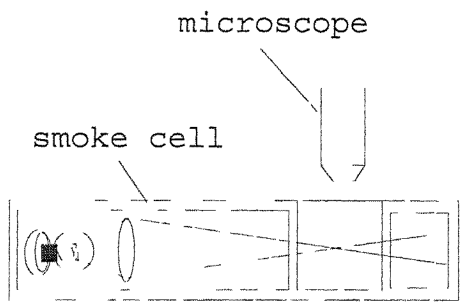
| | |
|---|---|
| Expt. 1<br><br> | Drop a little bit of food colouring or any other highly soluble coloured substance gently into a glass of water and carefully observe the changes taking place in the water.<br><br>Record your observations on the diagram at the left and indicate the movement of the colouring.<br><br>From your observations, try and describe what happens when the food colouring particles meet water:<br><br>____________________<br>____________________ |
| Expt. 2<br> | Can you guess what's inside the teacher's bag?<br><br>____________________<br><br>Explain how you guessed it.<br><br>____________________<br>____________________<br>____________________ |

**6. The particle movements are disordered, 'RANDOM MOVEMENTS'**

From what you saw earlier of the changes to the food colouring in water, did the colouring particles move in straight lines?

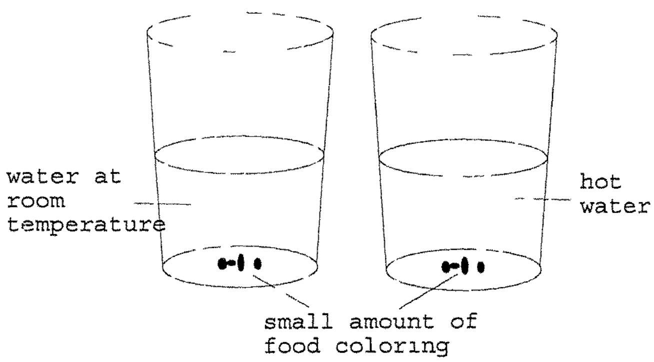
___

Draw in the box below your observation of how particles inside the smoke cell move under the microscope




This disordered movement of particles is called '**Brownian Motion**'.

**7. The speed of the particles' random motion increases with temperature**

| | |
|---|---|
|  | Put a little food colouring in 2 glasses containing water at room temperature and boiling water respectively. Compare the movement of the food colouring in the 2 glasses.<br><br>Record your observations.<br><br>___<br><br>From your observations, explain the differences between the particle behaviour inside the two glasses in terms of particle theory.<br><br>___<br><br>___ |