An exploration of the use of a 'Learning Study' in teaching evaporation and condensation in a Hong Kong primary school

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By

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To my late husband, Lo Yiu Fai Gustav and my daughter, Grace.

DECLARATION

This thesis results from my own work and has not been offered previously in candidature for any other degree in this or any other university.

STATEMENT OF COPYRIGHT

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Abstract of thesis

An Exploration of the use of a 'Learning Study' in Teaching Evaporation and Condensation in a Hong Kong Primary School.

In Hong Kong, primary science is taught as a component of General Studies, often by teachers who are not themselves science specialists. The need for in-service professional development within science is therefore a high priority. This study investigates one such attempt to add value to the teaching of science, thereby enhancing the participating teachers' practice and the pupils' learning. It considers one very detailed Learning Study case, focusing on the specific topic of condensation and evaporation, as it was conducted over a period of six months from 2002 to 2003. In that regard this study constitutes an instrumentalist form of case study, in which a single case is considered in great detail. At this meta-level of analysis the study seeks to establish how and to what extent a group of practicing teachers benefited from participating in the Learning Study, whether and what value was added to their professional knowledge.

However, the researcher, coming from higher education, as a lecturer at the Hong Kong Institute of Education, participated in the actual process of conducting the Learning Study. As a result, she also underwent professional development and gained in more deeply understanding the problems facing the teachers when faced with this particular topic. This study thus provided the opportunity for the researcher to both engage in the Learning Study as a participant observer, and also stand back from it and view it as a reflective practitioner. Very many Learning Study projects have been conducted in Hong Kong primary and secondary schools over the past seven years or so, across the whole curriculum subject range. And many claims have been made for its efficacy. It has its own very detailed form of action research methodology and underlying theory. This study attempts to unpack the various strands of both the theory and practice of the Learning Study. Thus, in addition to assessing the ways in which the Learning Study helped to address the problems of teaching science within the Hong Kong primary curriculum context, it also shows real teachers, grappling on an every-day

basis, with the problems that beset them in meeting the learning needs of their pupils, in their classrooms.

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Abbreviations

ARTE	Action Research in Teacher Education
CDI	Curriculum Development Institute
CF	Critical Feature
CLASP	Centre of Learning-Study and School Partnership
EMB	Education and Manpower Bureau
GS	General Studies
OL	Object of Learning
PDS	Professional Development school
PIPS	Progressive and Innovative Primary School

QEF	Quality Education Fund, Hong Kong
TIMSS	Trends in International Mathematics and Science Study
V1	Variation in pupils' prior understandings that may bear on what is to be taught
V2	Variation in teachers' conceptualization of the subject topic and in their ways of dealing with the particular object of learning
V3	Using Variation as a pedagogical tool

Chapter 1

The Origins, Aims and Scope of the Study

1.1 Science teaching in Hong Kong primary schools

In 1996, the Curriculum Development Institute (CDI), under the Education and Manpower Bureau (EMB), established General Studies (GS) as a main component of the Hong Kong primary school curriculum. This had important implications for the teaching of science. In short, science ceased to be a main subject in its own right and became a component part of General Studies, which also included Social Studies and Health Education. Prior to 1996, science was a discrete part of the curriculum, having two periods of study per week. Social Studies also had two periods per week and Health Education one period. Science, at that time, was predominantly taught by science graduates from one or other of the main Colleges of Education.

The main purpose of integrating the three subjects was to reduce the number of subjects offered in the primary curriculum and to avoid overlapping of content between different subjects. For example, before integration, in the domain of "Water", the Primary Science curriculum would include topics such as the "The three states of water", and "Formation of clouds, rain, mist and fog". The Social Studies curriculum would deal with topics like the "Use of water", and "The water supply in Hong Kong" whereas in Health Education there were topics like "The importance of water to our body". When these three subjects were taught by different teachers in schools, it was always possible that there would be an overlapping of content. So the CDI thought that integrating the three subjects into one coherent curriculum offering, would address that problem. However, the solution brought new problems. The central problem relates to the teaching of science in the context of General Studies. Specifically, it led to two main problems that remain to this day. These are:

1. The perceived status of science and the way it is taught, when it is a component part of the larger subject of General Studies;
2. Teachers teaching science even though they are not science graduates.

Both problems have a direct impact on the quality of science teaching and learning in Hong Kong primary schools. The origins of this study are set against these problems. Research undertaken in this study represents a major attempt to address the problems, both theoretically and in practice, as part of a more extensive move to introduce Learning Study into Hong Kong primary schools. Specifically, it considers in detail the result of introducing a Learning Study approach into one school with four General Studies teachers when teaching the topic of "Evaporation and Condensation". The difficulties encountered by the teachers will be considered and the way, in which they were resolved, through the application of a Learning Study, will provide a case study. It's recognised that one case study does not in itself provide the grounds for making any generalisations about the efficacy of the Learning Study approach in addressing the problems of teaching and learning of primary science. It does, however, provide evidence of how a small group of teachers came to clear and unexpected conclusions about their own teaching and this suggests a heuristic that can be applied to other teachers in similar situations, to address similar problems.

1.2 Teacher professional development: problems and possibilities

Against the background briefly outlined above, this study focuses on issues of teacher's professional development in the context of teaching science as a component of the General Studies curriculum. As noted, there are problems, mostly derived from the fact that science is not a discrete subject, but there are also possibilities in regard to teachers' professional development when teaching the science components; issues that will be taken up again in Chapter 7, when reflecting on the results of this study and its possible recommendations.

When General Studies was first offered in 1996, in Hong Kong primary schools, the demand for competent General Studies teachers was great. Usually, teachers from Social Studies or Health Education had to take up teaching this new integrated curriculum. With many of these teachers not coming from a science background, teaching this curriculum became very problematic. A teacher survey was conducted in 1994 by the researcher (Fu, *et al.*) before the implementation of the new curriculum on the perceptions of teachers who would take up the new curriculum of General Studies regarding difficulties they might encounter if they were to teach this integrated curriculum. A total of 1620 questionnaires were sent out to teachers in 81 primary schools, 859 questionnaires were returned. Among 50 survey items, teachers ranked the item about acquiring appropriate professional development in teaching this new curriculum as the top difficulty (85.1% agreed that it's difficult). The second and third were items related to their difficulties in using effective and appropriate teaching strategies in teaching General Studies (77.8% and 72.8% respectively agreed that they were difficult). This reflected the gap between initial preparation of science teachers, the in-service provision, and the implementation of the new curriculum, which places science within the broad subject area of General Studies.

In 2001, I had an opportunity to work with a group of primary science teachers. I was invited to observe their teaching on the topic "Change of states of water" to a class of age 9 children. Below are two episodes of lessons I observed.

There were about 30 pupils in the classroom, sitting in rows facing the teacher and the blackboard, which is the normal practice in Hong Kong classrooms. The language of instruction was Cantonese.

Episode 1

> *In this science classroom, Ms Lo was teaching the pupils the concepts of boiling and evaporation, she asked the pupils, "What happened to the water after it boiled? Where has it gone?" Frustrated by the pupils' silence, she continued, "It must have changed to vapour and gone to the air, right?" The group responded loudly, "yes." Then she asked Ho Chung, "Can you tell me where the water has gone?" Ho Chung answered, "It has changed to air." Ms Lo happily replied, "Yes, that's correct."*

The teacher prompted the pupils into making what she considered to be the right answer and the responses provided by the pupil were thus readily accepted by the teacher without further soliciting the pupil's scientific view of "air", or asking what the pupils meant by "it has changed to air". Is it part of the mixture of air or has it changed to gases like carbon dioxide or oxygen in air? Later in this thesis, I will refer to the literature, which shows that there is a considerable problem with children's expressions of understanding within science. Clearly, in this case, the teacher was reading off the pupil's answer at face value, rather than trying to probe what the pupil actually meant.

Episode 2

> *Ms Wong was boiling some water in a beaker and asked the class: "Have you noticed that the water has become less?"*
>
> *The class answered, "Yes."*
>
> *Ms Wong, "Good. Water has changed to steam and so becomes less. What do we call this change of state?"*
>
> *The class, "boiling."*
>
> *Ms Wong, "Correct. Now when I put a piece of glass over the top of the beaker, all of you can see some water drops on the glass, right? This change of state is called....."*
>
> *The class, "condensation."*

Pupils have a habit of remembering the key words or scientific terms in the topic, and the teacher in this episode was keen to find out if they could memorise the key terms. These key words or terms would become important for their examinations. The lesson continued in this manner for the whole period, with the teacher asking factual and "fill in the blank" questions. None of the pupils asked the teacher any questions.

These two episodes are generally representative of other science lessons in Hong Kong primary schools. Usually there is no group activity for the pupils, with very rare demonstrations by the teachers. Very often, there is no group discussion among pupils. The only information, which serves as the sole teaching materials, is the textbook. Rote-learning is common. The lessons are therefore very different from lessons based on a constructivist view of learning science; the approach that can only be achieved if teachers ask challenging questions, which in return stimulate the pupils to ask their own questions as the lesson proceeds.

The teacher preparatory programmes offered by the Hong Kong Institute of Education tried to respond to the shortage of General Studies teachers who did not have a science background, to help them face the challenge of implementing the integrated curriculum in 1996. From 1994 to 1999, all student teachers in the two-year Certificate of Education Programme were required to study a compulsory Primary Science module of 30 hours duration. The contents of this module were directly related to the topics included in the General Studies curriculum, hoping to prepare the student teachers better in their future teaching role as General Studies teachers. However, the limited training hours offered resulted in a great deal of concern about the actual competency of this group of novice teachers, when they claimed that they were able to teach General Studies in primary schools, upon graduation. At best this form of training was minimalist, and it helps to explain why both serving teachers and novice teachers were not well prepared to teach this integrated subject.

One of the aims of science education is to introduce pupils, from an early age, to the way scientific information is obtained from evidence in a systematic manner. However, this may be overlooked when arguments supporting integration are based on the belief that pupils can learn science better and more natural by exposing them to the interdependence and inter-relationship between people, things and their environment. This more naturalistic approach is in keeping with the notion of integrated General Studies, but it can only succeed if the teachers understand science thoroughly. However, as already noted, local studies have confirmed that the major difficulty perceived by General Studies teachers was their incompetence in teaching the science-related topic in the General Studies curriculum (Fu, *et al.,* 1994; So, *et al.,* 1996). The issue then becomes how to empower teachers in teaching the science-related components of the General Studies curriculum. Two possibilities spring to mind.

Obviously, one main possibility would be to insist that all teachers teaching General Studies have a firm science background as part of their initial teacher training. This has implications for the nature and structure of teacher education in Hong Kong, but at the moment this possibility has not been given proper consideration. The other main possibility is to deal with the problems as they arise in the day-to-day practice of teachers in their schools. In other words, to use a school-based approach to teachers' professional development, in which lecturers from higher education work alongside teachers in schools as part of a co-ordinated programme of professional development. Learning Study is one such approach, and it is the approach that was used in this study.

1.3 Addressing the problem: the Learning Study approach

Learning Study is a form of action research, which in this study was aimed at empowering teachers to bring about pupils' conceptual change regarding the concepts of evaporation and condensation. The Learning Study model, as developed by one Hong Kong research team, of which I am a member (Lo, *et al.,* 2005), claims to be an effective model of school-based and classroom-based teacher professional development. The practice of "Learning Study" is in part related to the systematic efforts of Japanese teachers in conducting in-depth research into their own lessons; the so-called "research lessons" (Lo, *et al.,* 2002; Pang and Marton, 2003; Lo, Marton, Pang and Pong, 2004). Stigler and Hiebert (1999) introduced the Japanese "lesson study" approach to teachers in the United States, suggesting that this may be the reason behind the apparent superiority of Japanese students in mathematics, evidenced by the international comparison produced by TIMSS. The results of the TIMSS study suggested that the main differences are in the style of pedagogy in Japan and America. Lesson study has then spread across some states in the United States over the past ten years (www.tc.columbia.edu/lessonstudy). This approach has been regarded by some teachers in the United State as an effective means for teacher professional development.

Learning Study in Hong Kong also bears some relation to Teaching Study as found in some schools in Mainland China. This is undertaken by "teaching research groups" where the time-table is designed to give space to conduct these meetings (Ma, 1999). The Hong Kong model is theoretically grounded in the Variation Theory (Marton and Booth, 1997; Pang and Marton, 2003; Marton and Tsui, 2004), originally developed at the University of Gothenburg, Sweden by Ference Marton, as part of what he calls phenomenography. It was introduced into Hong Kong when Marton was visiting professor at the University of Hong Kong. Central to this approach is the philosophical notion that originates in the modern period with Franz Brentano (1838-1917), that all mental activity, including learning, must have an object. In other words, one cannot learn without learning something, and that "something", in the context of Learning Study, is called the "object of learning". The theoretical base for this study will be discussed in much greater detail in Chapter 4.

As with the Japanese "lesson study", Learning Study in Hong Kong aims at enhancing pupils' learning and teachers' professional development as part of the same developmental process. Thus it deliberately conceives of pupil learning and teacher development as one overarching activity; as parts to a whole. Normally, within the Learning Study approach, teachers of the same subject teaching the same age group, in the same school work in groups of three to five. They meet regularly to jointly plan a research lesson, which is then taught by one of the team of teachers and observed by the group members who jointly discuss the lesson afterwards in a post-lesson conference. The lesson is then revised, especially with regards to resolving misunderstandings shown by pupils during the lesson. The cycle is repeated until all participating teachers have finished the round of teaching. The result is then shared among all the other teachers, either in the same school or from other schools.

1.4 Outline of this study

This study will focus specifically on the extent to which the Learning Study approach to enhancing pupils' learning and teachers' professional development was successful, in addressing the problems of teaching one science topic within the curriculum context of General Studies, outlined above. This chapter has been concerned with introducing the origins, aims and scope of this study. Chapter 2 reviews the relevant literature related to (1) pupils preconceptions and misconceptions of science, with a special focus on evaporation and condensation, (2) teachers' understanding of science and (3) classroom-based teacher professional development. The chapter concludes by stating the major research focus of this study. Chapter 3 provides a discussion of research methodology and justifies the use of the case study model. It also discusses action research as it applied within this Learning Study. Chapter 4 is also concerned with methodology, by describing the form of action research used in the Learning Study model and its implementation in schools. Chapters 5 and 6 consider the actual

Learning Study case as it was conducted in one particular Hong Kong primary school. Chapter 5 introduces the Learning Study design and data collections and then covers Stages 1 and 2 of the Learning Study. Chapter 6 discusses Stages 3 and 4 of the Learning Study, concerned with the final reflections on the project and the teachers' dissemination of their work. Chapter 7 provides the conclusion to this study and includes reflective comments on the Learning Study case as a whole. It examines the findings of this study from two major dimensions: (1) the primary science curriculum and the preparation of science teachers in Hong Kong, and (2) Learning Study as a platform for teacher professional development. The chapter acknowledges the limitation of this single case study, but nevertheless makes a number of recommendations.

Chapter 2

Literature Review

2.1 Pupils' preconceptions and misconceptions of science

Over many years of involvement in teacher education, I have frequently observed that teachers seldom think deeply about pupils' prior knowledge before designing their lessons. They are, of course, aware of where they have got to in the syllabus and what lessons the pupils have so far been given, but how that prior learning has impacted on the pupils' overall understanding of the subject often appears to be a bit "too theoretical" for many practicing teachers. This seems to resonate with the statement of Duit that "most teachers are not even familiar with the kind of pupils' pre-instructional conceptions that have to be taken into account when the right concepts are introduced (Duit, *et al.*, 2003, p.683). Teachers usually assume that they know what the pupils *don't know*. And they think that they know what the pupils *should know*. The curriculum and prescribed teaching materials in Hong Kong reinforce these assumptions, since they prescribe the required teaching content, which is to be taught or perhaps "delivered" to pupils, no matter how. The test and examination system in Hong Kong further reinforces these assumptions and imposes pressure on teachers to conform to what is required of their teaching.

At the same time, research over the past three decades in science education reveals a major theoretical and practical problem; that pupils enter their science lessons with already formed preconceptions about the science concepts/topics that they are going to learn. These preconceptions - many of which are misconceptions – become a serious block in their learning and their understanding of scientific concepts. As Johnson noted: "Despite extensive instruction in schools, studies were revealing a picture of poor understanding. No area of science, age or country seemed to be immune" (2005, p. 42). Howard Gardner (1997) puts the problem even more starkly when he notes that:

> *Even pupils who excel in physics at the best universities do not understand the meaning of the basic principles of the discipline. The very students who*

receive distinctions answer very much like five-year-olds once they are tested outside the school context. They believe, much as a young child does, in mysterious forces. When asked about what happens when the coin is tossed, they speak of forces being transferred from the flipping finger to the coin, slowly petering out as the coin rises, and then, when the coin has lost the transferred energy, it collapses to the ground. In truth, once the coin is released the only force acting on it is the downward pull of gravity. But it takes years of physics thinking to understand this deeply. (p.103)

Many researchers accept that pupils already hold their own ideas and, moreover, that these ideas are extremely resistant to change (e.g. Driver, 1986). From the perspective of developmental psychology, it has long been realised that pupil's prior knowledge is important in the achievement of learning (e.g. Ausubel, 1968; Bruner, 1960; Gagne, 1985; and Piaget, 1970). Some researchers go so far as to say that the primary task of science teaching is to induce conceptual change, with the purpose of achieving better learning results (Ben-Zit, *et al.*, 1986; Osborne and Cosgrove, 1983; Bar and Galili, 1994; Bar and Travis, 1991; Stavy, 1990; Tytler and Peterson, 2000). This means that the teaching and learning process must involve changing pupils' current concepts; it is not enough to supply new information in the belief that this is being "transcribed onto blank minds". This, in turn, means that teachers need to know what their pupils' current ideas are, and they need to focus on the best ways to facilitate conceptual change (Northfield and Symington, 1991).

There exists a large volume of study on the conceptual progression of children, such as Piaget's work, to match the logical demands of certain topic to the level of pupils' intellectual capability. The Australian Science Education Project (ASEP) and the Science 5/13 materials in the UK are two of the many projects that can provide relevant and valuable information to the curriculum designers. It is always a challenge for the curriculum designers in considering the sequencing of science topics in such a logical manner that they are well understood within the scope of the target group of pupils. Among these studies concerning conceptual change of children, a large volume of research literature is about the topics of evaporation and condensation. One of the first such studies was conducted by Osborne and Cosgrove (1983), in which they examined, across the age range 12-17 years, pupils' views about boiling, evaporation at room temperature, condensation and melting. They used a multiple-choice survey and in-depth interviews. They uncovered a number of non-scientific conceptions, and were rather pessimistic in their conclusion that while children could use labels like evaporation and condensation accurately, their understanding of these terms was not underpinned by scientific concepts. Moreover, views such as air being in bubbles of boiling water, or coldness coming through a glass containing ice to form condensation on the outside, persist for older children despite formal teaching. They found that some nonscientific ideas, such as that water breaks into hydrogen and oxygen when evaporating, increase with age (peaking at age 14-15 in this case). Similar conclusions are drawn by Driver, *et al.* (1994) and Garnett, *et al.* (1995). Tytler and Peterson (2000) conducted a research project to compare year 1 and year 6 pupils' concept of evaporation and condensation through group discussion, written responses and interviews. It is hoped that the findings can be used to evaluate other findings' claims concerning the progressions of children's concepts on evaporation and condensation. He found that there are substantial differences between these two groups of children, in the patterns of conceptions, the epistemological sophistication, and the structure of children's explanations. When most of the studies on conceptual progression are focused on conceptual/ontological aspects, his study has shown other dimensions, the epistemological and linguistic dimensions.

Bar and Travis (1991) studied primary school children's preconceptions of condensation and evaporation. Their findings were broadly consistent with those of Osborne and Cosgrove for older children, with some significant differences in detail. Bar and Travis identified a growing confidence over the 6-13 year age range, regarding the relationship between water and vapour, and the existence of vapour in air. They claimed that children from a young age understand that during the process of boiling, liquid is changed into gas. This claim has, however, been questioned by Johnson (1998a, p.582), who argued that the authors had no information concerning what these children *understand* by the gas state. Bar and Travis, he believes, underestimated the subtlety of the ways in which language can be used, accepting statements that water has "disappeared" at face value (whereas in fact children often use the term to mean "can no longer be seen"), or that children's use on the term "air" is meant in the same sense as adults understand it. Johnson (1998a, p. 569) argues:

> *These researchers have conflated a mist with the gas state, as if the distinction was of no importance. This conflation is unexpected, especially since they also note the paradox of most of these pupils saying the bubbles were "air" in other responses. Unless the pupils were using "air" as a general term for the gas state, and, therefore, meant that the bubbles were " water turned into an air" it seems difficult to see how one can say they appreciated this change of state for what it is – the water itself becoming a body of gas.*

It is clear from the literature (Piaget, 1929; Russell, *et al.,* 1991) that words like "vapour", "mist", "steam", "gas" and "air" are used loosely and even interchangeably by children. There is a common tendency in research on children's conceptions to impose adult meanings on children both in the phrasing of questions, and in interpreting the responses. Thus an important issue for research into children's ideas concerns how to understand what *they* mean by such language, in their particular contexts and on their own terms (Johnson and Gott, 1996; Johnson, 1998b). Andersson (1990) suggests that these terms should be regarded as synonymous, unless there is evidence to show they are not.

Bar and Galili (1994) conducted a related study which introduced a number of interesting features beyond their earlier study. They compared responses to questions about laundry drying and water evaporating from a saucer, and concluded there was a substantial dependence in children's views depending on context; a finding consistently supported in the recent literature (e.g. di Sessa, 1988; Driver, 1989; Galili and Bar, 1997; Tytler, 1998). In addition to context-dependency, these authors also identify four distinct views of children regarding the evaporation phenomena:

A. Water disappears, which is a view prevalent with younger children;

B. Water is absorbed into the surfaces, a view that appears at about age 7. This represents a move from a descriptive to a reasoning view in which children reconcile their adoption of a conservation view with the contradictory fact of water no longer being perceptible;

C. Water is transferred (evaporates) to another (upward) location such as the sky, clouds, ceiling or "air". The transition to this view occurs at about age 9, with children's developing views about air, but appears earlier with the boiling phenomenon because of the readily apparent agency of heat providing the upward move;

D. Water disperses into air, associated with a phase change. This view becomes predominant by age 13.

Bar and Galili, in their analysis, suggest that an acceptance of a conservation view underlies the A to B transition, although there is some ambiguity in their reporting. They found that Grade 4/5 children who expressed a clear understanding that air exists and fills the room were very unlikely to hold views A and B, whereas children who did not have this understanding mostly held these less sophisticated views. Progression in views about evaporation would thus seem to be driven by changes in the fundamental underlying conceptions (perhaps akin to Vosniadou's (1994) "framework theories") of matter, including the pervasiveness of air. Russell and Watt (1990) and Russell, Harlen and Watt (1989) put greater emphasis on the distinction between perceptible (steam) and imperceptible products of evaporation, and they focused on the distinction between the idea of displacement of water (without change in form, which includes water cycle images) compared to changes in form (see Andersson, 1990; Rahayu and Tytler, 1999). As we will see later, in Chapter 5, the issue of the visible and invisible phases of water became a critical feature in the Learning Study project. It is also a crucial issue in children understanding the water cycle in nature, which is a major topic of the curriculum worldwide. This study revealed that when the processes of condensation and evaporation are clearly grasped, pupils more readily understand the water cycle and other related natural phenomena.

Johnson (1998a, 1998b and 1998c), in a longitudinal study conducted over a period of three years (age 11-14), on secondary pupils' changing conceptualization of a substance within a succession of chemistry units, identified a number of critical features of the change. He argues that pupils' views about these different phenomena (the bubbles in boiling water, evaporation phenomenon, and condensation phenomenon) are both consistent and coherent, and that access to a conception of the gas state was critical in the development of their understandings. It would thus seem that there is some agreement concerning the fundamental ontological shifts that drive children's growing understandings of the evaporation and condensation phenomena. As Johnson points out, it may be necessary to introduce the "particle theory" in order to help children develop an understanding of the concepts of boiling, evaporation and condensation. His assertion of the need for pupils to understand this is different from the position of Bar and Galili (1994). However, he then made use of his findings to help his teaching by introducing the particle theory. This provides a good example of why teachers need to understand how pupils think and how they learn, if they are to improve pupils' learning.

The purpose of such a large volume of research into children's idea is to reveal the critical aspects of their learning with the hope of "that these findings can help frame advice to curriculum developers as to the appropriate sequencing of content, and to alert teachers to the critical features of pupil conceptions of phenomena that need to be negotiated in classroom learning" (Tytler and Peterson, 2000, p.340). In other words, teachers' understanding of pupils' prior knowledge is critical in enhancing their learning. The Learning Study that is described here also views this as pivotal, and it should serve as the start in planning any lesson.

2.2 Teachers' understanding of science

While the large volume of research findings on pupils' preconceptions and conceptual change in science contribute tremendously in regard to what is needed in teaching science, these studies have little to say about how, practically, teachers can be empowered to promote the conceptual change in classroom teaching and learning. In regard to *how* teachers can facilitate the conceptual change in classroom teaching, the research literature seems quite slim. Nevertheless, Philip Johnson, as mentioned above, in his three-year longitudinal study on pupils' conceptual change identified many ways in which the focus of teaching could be better matched to the needs of pupils as learners (Johnson, 2002). Based on his research findings, he and Roberts (2003) developed a teaching scheme in the form of a multimedia CD ROM that contains substantial changes to the original units in the British curriculum, by making use of the particle theory in helping pupils develop the concept of a substance.

Johnson (1995, 2005) rightly points out that in many available studies on children's conceptual change, details of the instructional background were not available. He admitted that this made it impossible to judge whether "adequate conditions for the acquisitions of the alternative orthodox conceptions were provided" (Hashweh, 1986, p. 242). What research on conceptual change has to offer classroom practice that cannot be set into normal practice to a substantial extent (Duit, 2003). Therefore, Arzi (1998) argued the need for studies that "followed pupils' ideas in parallel with instruction and beyond it" (p. 42.).

Many primary school teachers encounter difficulties with science and science teaching in Hong Kong. As previously noted, large numbers of primary school teachers enter science teaching with very little science background. This situation, however, is not only in Hong Kong, but also in many other countries (Fensham, Navaratnam, Jones, and West, 1991). It has been noted that many primary science teachers hold naive realist views of science as a body of discovered knowledge, separated from human beings (Abell and Smith, 1994; Gustafson and Rowell, 1995). These beliefs may well account for the fact that, for these teachers, learning science means memorizing facts and teaching involves presenting content (Abell and Smith, 1994; Young and Kellogg, 1993). Besides, many other studies also show that serving primary teachers often have a limited, sketchy or misinformed knowledge of the subject matter they are to teach (Atwood and Atwood, 1996; Ginns and Watters, 1995; Groves and Pugh, 1999; Summers and Kruger, 1993; Webb, 1992; Harlen, 1997). Teachers are less confident about their knowledge of science and its teaching than most other areas of the curriculum (Holroyd and Harlen, 1996). Harlen (1997) pointed out that it is not only in the UK but also in the US, Australia, South Africa, and Italy that the explanations many primary teachers could give of the concepts were at best incomplete. All these studies leave little room for doubt that increasing teachers' own understanding of science and thus empowering their content knowledge, as it bears on their pedagogy, is a key factor in improving the quality of teaching and learning in science. This is also one of the aims of this study.

The many research studies focusing on children's understandings across a full range of contents in 1980s (Pfundt and Duit, 1994) has had great impact on the teaching and learning process science education. In England, the Science Processes and Concepts Exploration (SPACE) project, which lasted from 1987 to 1993, studied children's ideas across the full range of concepts, and these influenced the National Curriculum. An extensive publication of this project can be found, e.g. Russell and Watt (1990a, 1990b). Another similar project, the Learning in Science project (Primary) conducted in the University of Waikato, also researched children's ideas about plants, animals, forces and motion, light and electric circuits (Freyberg, *et al.*, 1983). Children's ideas in these two different countries were consistent across the concepts studied. Harlen (2001) concluded that with the guidance of research findings into children's ideas, primary science education could be improved, in regard to three components related to teaching approaches. These components concerned (1) teachers and children's questions, (2) providing access to other related ideas, and (3) the teacher's own understandings of the subject matter. This has implications for teachers, when planning their lessons, with regard to the choice of teaching strategies. Appropriate professional development is thus pivotal to help the teachers and this study tries to address the above three concerns with the researcher working alongside them.

Because of the importance of children's (and teachers') prior knowledge that they bring to class, the classical conceptual change approach has become popular. Conceptual change, somehow, denotes the learning of science from a constructivist perspective (Duit, 1999) and has also been adopted in studies on learning and instruction in other fields (Guzetti and Hynd, 1998; Mason, 2001; Schnotz, Vosniadou and Carretero, 1999; Vosniadou, 1994). The article written by Driver and Easley in 1978 is frequently regarded as marking the beginning of the constructivist movement in science education. Constructivist learning implies a need to change teachers' practice, to bring about conceptual change. However, research has shown that even when teachers hold a constructivist view, they may not orient their teaching as a constructivist (Fischler, 1994). So it is deemed necessary to change teachers' views and actions. The TIMSS video study on Mathematics instruction in the U.S., Japan and Germany (Stigler, *et al.,* 1999) or the TIMSS-R video studies on science (Roth, *et al.,* 2001) investigated the "normal" practice of teachers and compared it to their views about teaching and learning. They found that their practice had not taken into account pupils' pre-instructional concepts. Prenzel and his team (2002) conducted a video-study of about 90 physics lessons taught by 14 teachers. Though only preliminary results are available, their (these 14 teachers) view of learning seems to be transmissive rather than constructivist. There is a gap between research findings about the importance of attending to the pre-instructional concepts in bringing about conceptual change and the instructional practice of teachers. It also suggests the importance of considering in detail, what kind of professional development is best able to help teachers. In this regard, in Hong Kong over the past seven years or so, claims have been made for the efficacy of Learning Study as a powerful means to professional development (Lo, *et al.,* 2005).

2.3 Classroom-based teacher professional development

Having described some current research on pupils' preconceptions and misconceptions of science and on science teachers' lack of subject knowledge and pedagogical knowledge, we now examine teachers' professional development, especially in regard to primary science education.

Over the past two decades, researchers have conducted various studies to examine the factors that enhance teachers' professional development. Various approaches have been investigated, such as co-teaching, collaborative teaching, and lesson studies. Co-teaching has been shown to improve many aspects of science teacher education, for example, as reported in the USA, (Roth and Tobin, 2005), in Canada (Roth, Lawless and Tobin, 2001), and in Australia (Rigano, Ritchie and Bell, 2005). Most of the research uses an ethnographic methodology in which researchers participate in the process of co-teaching as participant observers. This approach is able to provide rich data on the diversity and multiplicity of classroom interactions as they are evidenced during and after co-taught classes. Observations made are primarily influenced by sociocultural theory, as found for example in Bourdieu (1977, 1986), Sewell (1992) and Roth and

Tobin (2004). The rich date produced helps teachers to understand better how a co-taught lesson should be as to enhancing pupil learning. The Learning Study can provide similar experience as in co-teaching model.

Team teaching is a strategy that has been around for years, but when used in the context of teachers' professional development its main application has often been as part of teacher induction programmes, where a beginning teacher is teamed up with an experienced teacher. Alternatively, it can involve two or more experienced teachers sharing in a joint project across subjects, where each adds his or her own expertise to a common them explored in a series of lessons. The impact on each teacher's professional development can be considerable, as it provides an opportunity to see colleagues in action. This same benefit is found in the Learning Study approach, as evidenced in the study.

Much attention has also been devoted to investigating the effects on teachers' beliefs and attitude towards science (Haney, Neuman, and Clark, 1969; Koballa and Crawley, 1985; Morrisey, 1981; Munby, 1983). In Hong Kong, So (1997) used a qualitative approach to uncover a teacher's thinking process during lesson planning, to gain a more holistic view of the structural complexity of teacher cognition in the process of planning a lesson. It is no easy task to plan an effective lesson. Though this study has no intention of looking deeply into teachers' thinking process, it shows certain elements of its complexity. Wynne Harlen (1997) carried out research for a period of two years into primary teachers' understanding of concepts in science and technology and her research reveals that in regard to the teaching of concepts in science, teachers are commonly recognised as one of the key agents in inducing pupils' conceptual change. Teacher development programmes are therefore essential in order to enhance teachers' own understandings of science and change their views of teaching and learning and hence their practice. The question then arises: What kind of professional development programme is perceived by teachers as effective to enhance pupil learning? The present research is concerned with that question, in particular what can teachers do to bring about conceptual change in pupils? Answers to these questions obviously have significant implications for teacher education and teachers' professional development.

Improving classroom teaching is receiving attention from researchers investigating ways of increasing pupils' learning (Lampert, 2001; Stigler and Hiebert, 1999). Research findings strongly support the view that professional development programmes which are long-termed, school-based, collaborative, focused on pupils' learning and linked to curricula are likely to be regarded as effective in the eyes of the teachers (Darling-Hammond and Sykes, 1999; Garet, Porter, Desimone, Birman and Yoon, 2001; Joyce, Wolf and Calhoun, 1993; Loucks-Horsley, Hewson, Love and Stiles, 1998; National Staff Development Council, 2001). But significantly teachers rarely make use of what they have learnt in the programmes to improve their practice (Huberman, 1989; Richardson and Placier, 2001). Even though some special programmes have demonstrated that, with carefully designed support, teachers can use certain research findings to improve their practice (Carpenter, Fennema, Franke, Levi and Empson, 1999), there is the concern that too little of the educational research can be of use for teachers to improve their classroom practice (National Educational Research Policies and Priorities Board, 1999). "It is also well recognised that practitioners rarely alter their practice on the basis of research findings." (Lather, 2004, p. 760) Educators have recognized the difficulties of translating the research knowledge into forms that teachers can use to improve their practice, such knowledge may be of a very different kind from those produced by the researchers (Cochran-Smith and Lytle, 1990, 1993; Doyle, 1997; Eisner, 1995; Huberman, 1985; Kennedy, 1999; Leinhardt, 1990).

Knowledge of how to teach, called by some researchers as craft knowledge, is characterized more by its concreteness and contextual richness than its generalisability and context independence (Hiebert, Gallimore and Stigler, 2002). Hiebert and Stigler (1999) recognized the value of craft knowledge and asked if it's possible to build personal craft knowledge into a trustworthy knowledge base that can be shared widely by the profession? They began to explore the possibility of building such a knowledge base by beginning with practitioner's knowledge. What is practitioner's knowledge? This is the kind of knowledge that practitioners (teachers) generate through active participation and reflection on their own practice. The emphasis on reflection moves it beyond craft knowledge. In Chapter 3 we will refer to this by using the term "praxis", derived from Greek and contrasted with the kind of knowledge known as "techne".

One of the means that Stigler and Hiebert (1999) have suggested to facilitate the transformation from craft knowledge to practitioner knowledge is through doing a Japanese Lesson Study. They have popularised the Japanese Lesson Study and, in the USA, this has generated renewed interest in the notion of lesson study and lesson analysis. Over recent years, a number of researchers have therefore used forms of lesson study as part of teachers' professional development (Lewis, 2002). This has taken its place alongside a number of other innovative approaches, such as peer coaching, teacher research projects, university-school partnerships, and the professional development school (PDS) model.

Lesson study is a professional development process in which teachers engage to systematically examining their practice, with the goal of becoming more effective. It may best be regarded as a continuing in-service professional development programme (Fernandez, *et al.,* 2003, Lewis and Tsuchida, 1997, 1998). Working on these study lessons involves planning, teaching, observing, and critiquing the lessons. To provide focus and direction to this work, the teachers select an overarching teaching goal that they want to explore. The teachers jointly draw up a detailed plan for the lesson, which one of the teachers uses to teach the lesson as other group members observe. The teachers then come together to discuss their observations, with the result that they may revise the lesson, which another teacher will teach, as other members of the group observe.

Hiebert, Gallimore and Stigler (2002) point out that lesson study groups can generate knowledge that share the three key features with practitioners' knowledge:

1. The knowledge generated is linked with practice – the group members work on a problem that is directly linked to their practice.

2. The knowledge is detailed, concrete and specific – the group members discussed how the knowledge could be made most comprehensible by pupils, carefully designing the lesson and choosing appropriate examples for illustration, bearing in mind that different combination or different examples may trigger different learning.

3. The knowledge is integrated - the practitioner knowledge, as identified by Shulman (1986) which includes content knowledge, pedagogical knowledge and pedagogical content knowledge, together with knowledge of the pupils (what they know and how they know), are intertwined to facilitate pupil's learning.

The Hong Kong version, which is called Learning Study, is a systematic process of inquiry into classroom teaching and learning employing an action research methodology and has the improvement of classroom teaching and learning at its core. Unlike lesson study in Japan, the Learning Study approach puts together teachers' teaching and pupils' learning at its focus. By singling out teachers' and pupils' different ways of perceiving the same object of learning, teachers are thus made more sensitive to pupils' prior knowledge. In selecting out the critical features of the object of learning and using the Variation Theory as an instruction tool, the aim is to enrich the pupils' learning experience (Lo, *et al.,* 2005). My research will examine this model to assess the extent to which it contributed to the professional development of one group of primary science teachers.

2.4 Summary of the literature review

This section provides a summary of the studies discussed in the above literature review, in particular, the review on the importance of understanding children's prior understanding and conceptual change in science teaching, especially on the concepts of evaporation and condensation. However, there are not many studies say about how practically teachers could be empowered to promote the conceptual change in classroom teaching and learning. The section continues to examine factors that can enhance teachers' professional development. A consensus have been arrived at in that professional development programmes which are long-termed, school-based, collaborative, focused on pupils' learning are more likely to be regarded as effective. Based on the above factors, how the Japanese lesson study facilitates the transformation from craft knowledge to practitioner knowledge is reviewed. It ends by introducing a professional development model recently developed in Hong Kong, the Learning Study.

2.5 The research questions

This research is therefore an exploration of the use of a Learning Study in teaching evaporation and condensation in a Hong Kong primary school. This exploration focuses on the following three related questions:

1. Is the empowerment of teachers through Learning Study action research critical and significant in contributing to their professional development?

2. How is teacher professional development linked to pupils learning?

3. How and to what extent can we change the pupils' conceptual understanding of evaporation and condensation through Learning Study action research?

The reason why the concept of water evaporation and condensation was selected is that this is one of the most difficult but also interesting topics that school teachers in Hong Kong have to grapple. At the same time, as we have seen above, there is already a large body of literature in various countries on the same topic, or related topics such as the "water cycle", "the three states of water" and "evaporation and condensation of water". The available data in the literature of other countries can be used as a rich reference for the present investigation on teacher professional development when conducting the Learning Study.

Chapter 3
Research Methodology

Research in education can be broadly divided into two different kinds: quantitative and qualitative research. This chapter will provide an initial introduction to both forms of research, specifically discussing case study and action research, which are essentially qualitative approaches. This study centres on a single case of Learning Study in primary science, conducted as part of the Progressive and Innovative Primary Schools (PIPS) Project, within which 50 Learning Study cases were conducted across all subjects on the Hong Kong primary curriculum. Learning Study has its own research methodology, which is a form of school-based action research. The actual form that action research takes in a Learning Study will be discussed in detail in Chapter 4.

One main purpose of this chapter is therefore to describe and explain the research methodology this study has used in attempting to unpack the Learning Study approach as it applied to one topic within primary science and to ask, within the confines of this one case, whether Learning Study proved to be an effective way to bring about professional development of the participating science teachers. The assessment of this case as a whole and the recommendations that arise from this case are reported in Chapter 7, but they emerge throughout the thesis and will be considered as they emerge, when describing the case in process.

3.1 Quantitative research methods

There are currently two major paradigms within the social and education research. One is referred to as the "scientific method" or "positivism" (Lincoln and Guba, 1985). This type of research mainly associates with a quantitative method of approach. Its findings, in other words, are *generalisable* and can therefore be used for *predictive* purposes. Stringent efforts would be made to ensure that the data gathered is statistically valid or the conclusions will be tainted. And every effort is made to make the research *objective* and *repeatable*. However, in this process, generally there is much personal commitment on the part of the researchers and so the idea of neutral objectivity is being challenged. The results of this debate within the natural sciences impacted on the social sciences and education. It opened the way for recognising the "subjective" features within research and in fact including them within the research process.

Anthropologists had included the subjective views from the start and with the decline of Positivism ethnographic studies became much more acceptable. Action research has also benefited from this change of attitude, and when applied to education it began to get much closer to the teachers and students in their actual school situations. In short, qualitative research became respectable and began to make a real impact in education research. In the case of this study, the qualitative research method is considered and will be discussed in the section that follows.

3.2 Qualitative research methods

This study uses qualitative approaches, and these emphasise the importance of the social and personal contexts in understanding the social world and how individuals make meaning from their experiences. This is the main reason I have chosen this approach. My study focuses on the local conditions that operate as individual teachers grapple with their teaching and the challenges it presents them. In this study I observe a group of science teachers working in the local curriculum context of Hong Kong and the particular teaching and learning contexts that prevailed in their school and classrooms, as they grappled with the challenges of teaching their pupils the concepts of evaporation and condensation. Also, how they tried to improve their teaching in these specific contexts, as a result of participating in the Learning Study. Unlike quantitative research, the results are not intended to be objectively generalisable, though there are points that we will suggest arising from this study that *might* have some general application; relating in particular to the needs of "under-trained" science teachers working in the context of General Studies, and in the application of the Learning Study process. These will be taken up in Chapter 7, but for the moment, the point to stress is that qualitative research, as a whole is not attempting to generalise, but instead focuses on the specific qualitative features of teaching and learning.

Three strengths of qualitative research have been identified by Miles and Huberman (1994):

1. Qualitative data reflect on actions instead of on behaviour. Actions can be defined as carrying with them the intentions and meanings of the actor.

2. These actions are context specific and hence reflect what "real life" is like.

3. The strength of qualitative data is the fact that it reveals the meanings that people give to what happens around them.

In this present study, the interactions between the participants and the researcher, as well as between the participants and their pupils were analysed. The researcher took a holistic perspective, which means considering every action or discourse as part of the whole phenomenon of the target group. As Patton (1980, p.40) stated: "A holistic approach assumes that the whole is greater than the sum of its parts'. Creswell (1994, p.1-2) defined qualitative research as "an inquiry process of understanding a social or human problem, based on building a complex, holistic picture, formed with words, reporting detailed views of informants, and conducted in a natural setting". Qualitative research is communicative research, looking for more in-depth, direct findings through in-depth interviews, case study and observation, etc., which allow the researcher to look at the interconnectedness among different factors.

Qualitative research has been said to rely less on reliability, validity and generalisability, as in quantitative research, and more on apparency, verisimilitude and transferability (Connelly and Clandinin, 1990). Lincoln and Guba (1985) suggest the important elements of credibility, transferability, dependability and confirmability in qualitative inquiry. Therefore, the qualitative-research methods for gathering data in this research included pupil and teacher interviews, observation of lessons taught by teachers, discussion notes of the Learning Study meetings, and the reflection of the teachers one year later. The purpose of using these methods is to provide triangulation. The results from these methods can be compared against each other and the researcher can thus gain a more complete understanding of the professional development of the teachers. To record the data, note taking, audio or video-taping were used. It should be noted that all audio and video data were provided in Cantonese, and then transcribed and translated.

It is also important that the qualitative researcher considers every case as unique and tries to take into account the different context-specific variables that may influence behaviours. In this case study, the four teachers participating in the Learning Study process are different and we value these differences. At the end, each individual's professional development may also be different.

To conclude, there are three important elements about the present research: Firstly, it is a subjective research, researching natural settings. Secondly, data is collected from different sources, emphasising the interaction between variables. Thirdly, the study is looking for relations, patterns and comparisons (Smith, 1987). These characteristics justify the use of the case study method, which now needs to be considered in more detail.

3.3 Justification for a case study approach

Case-study is a means of getting to the specifics of a social phenomenon and its methodology underwent change and development in the twentieth century. The Chicago School of Sociology described this method as:

> *In essence, the term "case study" referred to the collection of detailed, relatively unstructured information from a range of sources about a particular individual, group or institution, usually including the accounts of subjects themselves.*
> (Hammersley, 1989, p.93)

However, another renowned researcher in the field, Sturman, an Australian researcher, had a different notion about the view that a case study is a collection of unstructured information. He said:

> *...the distinguishing features of a case study is the belief that human systems develop a characteristic wholeness or integrity and are not simply a loose*

collection of traits. As a consequence of this belief, case study researchers hold that to understand a case, to explain why things happen as they do, and to generalise or predict from a single examples, requires an in-depth investigation of the interdependencies of parts and of the patterns that emerge. (Sturman, 1994, p. 61)

Yin (2002) sees the case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not as so clear, there will be many more variables of interest than data points; relies on multiple sources of evidence to enable data to converge in a triangulation fashion, benefits from the prior development of theory to guide data collection and analysis. He wrote:

> *...theory development prior to the collection of any case study data is an essential step in doing case studies.* (p. 28)

Yin's requirement for structure in the case study is more stringent than Sturman – because of his stress on the need of a theoretical framework to guide data collection. But Robson (1993) recognizes the fact that both the "prestructured" and "emergent" designs are necessary between looseness and selectivity. Stake (1995) writes about using issues to guide the case study. There are the "etic" issues, which are issues brought to the case by the researcher from the outside. But later, the "emic" issues will emerge; issues that belongs to the actors in the case. My case study is more in line with the Robson's and Stake's perspectives.

Yin (2002) also points out the need to differentiate between the case study, which is a research method, and the case (its object). He suggests the main difference between the case and the case studies as follow:

> *.....(The case) can be some event or entity that is less well defined than a single individual....and case studies have been done about decisions, about programs, about the implementations process and about organisational change.* (p. 22)

However, Stake (1994) argues that a case study is not a methodological choice, but a choice of object (the case) to be studied, because we can use different methods of inquiry to carry out the case study. He wrote:

> *As a form of research, case study is defined by interest in individual cases, not by the methods of inquiry used.* (p. 236)

So Stake (1995) defined the case as an object rather than a process. He used the example of a teacher who could contribute to a case but not her teaching because it lacks specificity. He referred to the case as an integrated system working parts:

> *.....(The case) is likely to be purposive, even having a "self". The case is an integrated system. The parts do not have to be working well, the purposes may be irrational, but it is a system. Thus people and programs clearly are prospective cases. Events and processes fit the definition less well.* (p. 2)

Stake (1994) has classified three types of case study: the intrinsic case study, the instrumental case study and the collective case study.

- the intrinsic case study – when one wants to understand a particular case in depth. The interest is in the case itself, the purpose is not to understand some abstract construct or generic phenomenon.
- the instrumental case study – is to provide insight into an issue through the examination of a particular case. The case itself is of secondary interest.
- the collective case study – researchers study a number of cases jointly in order to inquire into a phenomenon, or to understand a still larger collection of cases. It involves an instrumental study extended to several cases.

As my study is undertaken to examine the nature and efficacy of Learning Study as revealed in one particular case of primary science, it is predominantly an instrumental case study. Its aim is to provide insights into Learning Study as a professional development process, through the examination of a particular case. As with other instrumental case studies, the case itself is of secondary interest. The primary interest is in the Learning Study and the extent to which those who participated gained in professional development, through engaging in the Learning Study action research process.

3.4 The action research approach

This case study investigates how the teachers became action researchers through undertaking Learning Study, with the researcher working closely alongside them. This mirrors the approach to action research found in much of the literature coming out of the British tradition, where action research is linked to the enhancement of teachers' professional practice. Action research in classroom emerged in the 1960s and early 1970s, responding to the curriculum movement concerning learning context in the classrooms from "memory" and "routine problem-solving" to "understanding" tasks. The problems that teachers experienced in such movement resulted in a number of national projects in collaboration with teachers to investigate classroom research (Barnes, 1976; Elliott and Adelman, 1976; Elliott and MacDonald, 1972; Jenkins, 1977; Parlett and Hamilton, 1973; Smith and Schumacher, 1972; Walker and Adelman, 1972; Wild, 1973). Elliott (1978) called this alternative mode of research action research and has participated actively in many projects, just to name two, the Stenhouse's Humanities Curriculum Project (1971) and the Ford Teaching Project (Elliott and Adelman, 1976) which look at classroom research and how it can help professional development of teacher in effective teaching. Later in year, Carr and Kemmis (1986) provide the following definition for action research:

> *Action research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices, and the situations in which the practices are carried out.* (p. 162)

This notion of action research positions itself very closely to the notion of teachers as reflective practitioner; a term coined by Donald Schon (1983). Elliot (1991) develops his interpretation of action research as a form of teacher professional development, which emphasises the view of conducting the action research as a means of promoting reflective practice. There is another trend in action research which is emphasised particularly in the USA. In this tradition, action research is referred to as "the systematic collection of information that is designed to bring about social change" (Bogdan and Biklen, 1992, p.223). Nevertheless the two different approaches are not mutually exclusive. The reflective practitioner is actively involved in the process of collecting information, but in this case it is not social change that is often the prime target, but rather the practitioner him or herself. This is particularly relevant to the case being reviewed for this thesis, where the participating teachers were not mainly aiming at social change, but rather personal change in the way they approached their teaching, which they shared inter-personally with each other.

Many researches have indicated that teachers found it difficult to master action research and facilitators also experienced problems in offering the right kind of support to the teachers (Johnston, 1994; Elliott, 1991; Zeichner and Noffke, 2001). The positive findings from the ARTE (Action Research in Teacher Education) International Project (Ponte, 2002a) show the simultaneous development and application of professional knowledge by teachers through conducting action research. This knowledge is what Grundy referred to as the knowledge of praxis (Grundy, 1998):

> *...professional knowledge is knowledge that is intrinsically connected with practice. This is not knowledge that informs practice, or that has practical intent, but knowledge which is embedded in "praxis": reflective knowledge in and through action.* (p.40)

Ponte (2002b) pointed out that teachers gain insight into the way action research could be used via praxis. Teachers do use techne and theory (knowledge of techne) but this only becomes praxis when teachers determine and take responsibility in their own practice. Ponte also stressed that teachers could learn better when they are under the facilitation situation. The Learning Study can be compared to such situation. I am the facilitator who conducted the action research with the group of teachers. In conducting the Learning Study, which takes the form of action research, it bases on four key assumptions, very much similar to that of the ARTE project led by Ponte (2002b, p. 400).

- *Action research is geared to teachers' own practice and the situation in which that practice takes place.*
- *In action research teachers engage in reflection based on information they have systematically gathered themselves.*

- *Action research is carried out through dialogue with colleagues within and outside the school.*
- *In action research pupils (or other target groups of practitioners) are used as an important source of information.*

Learning Study provides the framework for teachers to systematically go through the action research cycle. As Ponte (2002b, p. 420) has put it "This leads to the assumption that teachers come to see the purpose of action research by doing it and they start to do it when they start to understand its purpose." As will be apparent later, when we view the Learning Study process in Chapter 5, the teachers in this case went through the process over four teaching cycles, and as they increased their understanding of the action research process they increasingly took ownership of it. By the time they came to their final presentation and also when interviewed one year after the case, it was clear that they not only saw the purpose of action research but also appreciated its contribution to their practice. Elliott (1991) pointed out clearly that in participating in action research, teachers are provided the opportunity to collaborate with others in evaluating their practice and raise their awareness of their own personal theory, and thus a shared theory of teaching by researching can be developed. Torbert (2004) also noted that "Knowledge is always gained through action and for action. From this starting point, to question the validity of social knowledge is to question, not how to develop a reflective science about action, but how to develop genuinely well-informed action—how to conduct an action science". All of this was very apparent in the Learning Study case I conducted.

One final point, many writers, including Cohen and Manion (1989), Stake (1994) and Yin (1993) have used different ways to say that generalisations are only applicable within the overall population to which the individual case study applies. For example, Cohen and Manion (1989) have noted that:

> *...the case study researcher typically observes the characteristics of an individual unit – a child, a clique, a class, a school or a community. The purpose of such observation is to probe deeply and to analyse intensively the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalisations about the wider population to which that unit*

> *belongs.* (p. 124-5)

Lawrence Stenhouse (1988, p. 49) has however noted that:

> *Sometimes, particularly in evaluation research, which is commissioned to evaluate a specific case, the case itself is regarded as of sufficient interest to merit investigation. However case study does not preclude an interest in generalisation, and many researchers seek theories that will penetrate the varying conditions of action, or applications founded on the comparison of case with case. Generalisation and application are matters of judgment rather than calculation, and the task of case study is to produce ordered reports of experience which invite judgment and offer evidence to which judgment can appeal.*

As mentioned above, though the aim of this case study is not to find generalisations, there are, nevertheless, points that might well apply beyond this case to other teaching situations in Hong Kong, where similar situations prevail. As Stenhouse mentions, these are matters of judgment and we will consider them as such when they are reviewed in Chapter 7. We will now look, in Chapter 4, at the way the action research process has been adapted to meet the needs of Learning Study, as it is used in Hong Kong.

Chapter 4

Methodology:
The Action Research Framework of Learning Study

Learning Study is a form of action research. As previously noted in Chapter 1, Learning Studies conducted in Hong Kong bear some similarities with lesson studies in Japan and teaching studies in parts of Mainland China. Nevertheless it has its own unique characteristic, in that it is theoretically grounded in the Variation Theory (Marton and Booth, 1997), which places the primary focus on the "object of learning" (Pang and Marton, 2003; Marton and Tsui, 2004). The Variation Theory therefore provides the major theoretical framework for this study. This theoretical framework has the following characteristics:

- it focuses on the object of learning;
- it is premised on three types of variations

4.1 The object of learning (OL)

The concept of the object of learning is derived from Franz Brentano's principle of "intentionality" (1874). Intentionality is concerned with the directedness of the mind. All mental activity requires an object. One cannot think without thinking about something; one cannot be conscious without being conscious of something. Thus to say "I learnt" without identifying *what* has been learnt is meaningless. Learning must have an object and in the context of learning study this is called the object of learning. When learning occurs it will therefore always have an object. For any given lesson, on any given topic, it should therefore be possible to quite closely define the intended object of learning, though of course what pupils actually learn might be quite different from what they are intended to learn. The Variation Theory is posited on the view that in order for pupils to discern the object of learning they need to be able to experience variation. For example, in this study, children experienced variation in the way in which condensation occurred using the same object (not varied) placed in different temperature settings (varied). Using the play of "varied" and "not varied' in this way, it is claimed, aids discernment.

With any given topic, there will be a number of critical features that need to be identified, if the object of learning is to be discerned. These may be also viewed as potential stumbling blocks to learning, if they are not attended to. For example, the linking of evaporation to condensation in this study was aimed at addressing an important critical feature to develop this sophisticated understanding. From the findings of the large volume of literature in children's ideas discussed in Chapter 2, in order for pupils to discern the nature of both condensation and evaporation they have to appreciate the invisible nature of water vapour; though it cannot be seen it still exists in the air. Without that understanding, pupils will not have a complete and scientific appreciation of condensation and evaporation. It is thus a critical feature of learning the concepts of condensation and evaporation. Given this general overview of the Variation Theory, we will now consider three types of variation, as employed in this Learning Study.

4.2 The three types of Variations

4.2.1 Variation in pupils' prior understandings that may bear on what is to be taught (V1)

It has long been recognised that pupils' prior conceptions and misconceptions can have a major impact on what they learn, especially in science. As this is so pervasive and influential on learning, teachers need to be fully alert to this phenomenon and take it into account when planning, conducting and analysing lessons. This phenomenon is captured within the process of learning study in the concept of Variation 1 (V1), where there are three main ways of identifying pupils' prior conceptions; pupil interviews, pre-tests and constant observation during the lesson. Any topic can have different objects of learning, depending on what its precise focus is chosen to be, and identifying pupils' prior understandings provides the starting point, when deciding an appropriate object of learning for a given topic, with a particular class. Identifying prior understandings also has a major bearing on the process of identifying the critical features for any given lesson.

Pupils vary in their prior understandings and it is the aim of the Learning Study model to identify these and act on them in planning and teaching a given lesson. In the process of planning a lesson, pupils are interviewed. The interviews take two different forms. Researchers interview pupils who have learnt this topic in the previous year, to find out what they retained and also misconceptions that they appear to retain. Researchers also conduct an interview with a random selection of pupils from classes which will be taught the topic, to try to find out some of the prior understandings that they will bring to their learning. As this only represents a small sample it cannot be definitive, and teachers therefore need to be continually on guard when teaching the lesson, as other conceptions and misconceptions surface. The results of these two forms of interview feed into discussions about the precise object of learning, the critical features that need to be addressed in the lesson and ultimately the overall sequence of the lesson content, so that the process of learning is progressive.

The pre-test is also part of the overall process of gathering information about pupils' prior understanding. The group interviews provide a sample guide to understand pupils' thinking and they assist in the design of the pre-test. As the pre-test is given to all pupils participating in the Learning Study it is able to reveal conceptions and misconceptions at a more individual level, to aid information gathered from the group pupil interviews. The pre-test is diagnostic in nature, so that it opens up the space for pupils to freely express themselves and their own ideas. For example, in this study, the pre-test contains four open-ended questions which were intended to elicit pupils' current understanding of some daily phenomena related to the concept of evaporation and condensation.

During the course of the lesson, teachers are encouraged to pay particular regard to the understandings and misunderstandings that arise in the process of presenting ideas and classroom discussions. This applies not only to the teacher who is teaching but also to other members of the team as they observe the lesson. Indeed, because of the normal pressures on a teacher when teaching in front of colleagues, those observing may be better placed to identify aspects of children's thinking as revealed in the way they respond to questions and ask questions of the teacher. These collective observations are carried back to the post-lesson conference, where they are discussed in such a way that they might change and improve the lesson plan for subsequent lessons.

4.2.2 Variation in teachers' conceptualisation of the subject topic and in their ways of dealing with the particular object of learning (V2)

4.2.2.1 Variation in teachers' conceptualisation of the subject topic

As previously noted, there is often a major problem with teachers' conceptualisation of the subject topic in science, particularly in the context of Hong Kong where many teachers teaching science do not have a science background. Clearly, it is not appropriate to give subject teachers a pre-test, as is done with pupils. However, if pupils are to gain in their learning, it is imperative that what they are taught is accurate. The process of identifying and hopefully correcting teachers' misconceptions has to be handled with subtlety and within the Learning Study process. This is accomplished over the many discussions that form part of the overall process of a Learning Study, many of which occur before the practical teaching cycles begin. They may arise, for instance, in the context of discussing pupils' misconceptions. In this study, there was one very obvious example when teachers were trying to untangle pupils' misconceptions about where the water vapour has gone after evaporation, and it gradually transpired that they themselves were not sure.

Other main occasions when teachers are able to examine their own understandings include the marking and analysing the pre- and post-test, engaging the lesson observation and the post-lesson analysis. Reading through and analysing the result of the pre- and post-test involves the attempt to try to get into the minds of the pupils, to work out what they are actually thinking when providing their answers. What they say in their answers may not be precisely what they mean and teachers therefore have to act as "detectives". In doing so, their own understandings are up for scrutiny, though this may be conducted as a purely private exercise, particularly in the Hong Kong context, where teachers do not want to lose face in front of their colleagues. Through engaging in this process of analysis, teachers are thereby gaining in reflective professional development.

Open discussions between teachers are encouraged in the many planning meetings and in the post-lesson conferences. Here, teachers "hammer out" and shape their own understandings in the process of inter-person dialogue. The topic of the conversation is invariably focused on the object of learning, critical features and the overall lesson plan. In the process, teachers not only advance in their personal understanding of the topic, through listening to each other, they also apply their ongoing re-conceptualisations to the lesson plan.

4.2.2.2 Variation in teachers' ways of dealing with the particular object of learning

A second form of teachers' variation (V2) relates to their previous experience of teaching the same or similar topic. This is brought into the discussions in recognition of the fact that teachers vary considerably in the way they teach a lesson, even when staying close to the textbook topic. The tacit, personal practical knowledge (Elbaz, 1983; Connelly and Clandinin, 1995) that teachers have developed about their pupils, their pedagogical content knowledge (Shulman, 1986), their understanding about the content, etc. are valued, sharpened and made explicit as the teachers and researchers share their ideas in preparation meetings before the research lesson, when observing team members as they teach their research lessons, and when engaging in professional dialogue in post-lesson conferences. In this way, Learning Studies aim to break the isolation of teaching and engage teachers as participants in a developing learning community.

4.2.3 Using Variation as a pedagogical tool (V3)

In addition to variations in pupils' and teachers' conceptions, and in the different approach to pedagogy teachers have previously employed, variation is used as a pedagogical tool. As noted previously, considerable emphasis is placed on inducing discernment through exposing pupils to variations in the way they experience phenomena. In planning the lesson it therefore becomes important to use variation in designing teaching episodes and practical activities. In this study there are many examples of the use of variations as a pedagogical tool. For example, in the lesson, pupils were given three varied situations in which evaporation takes place; the 5 ml of water in the test tube after boiling, the 5 ml of water in the test tube placed in the classroom after three days and the plate of water placed at home.

A crucial point in the use of variation is that it should be controlled and systematic in every case. That which is varied and that which remains invariant is intended to impact directly on the pupils' discernment of the object of learning. It is a fundamental point in Variation Theory that teachers often use variation in their teaching, but do so in a haphazard way, varying many things at the same time. By systematically keeping some things invariant while others are varied and then changing what is varied and what remain invariant, pupils are able to "see" (directly perceive or intuit) the object of learning. In Chapter 5 of this study, I describe how the pattern of variation operated as a pedagogical tool in this case, and how that enabled the pupils to discern the object of learning.

4.3 The Learning Study model

As noted in Chapter 2, Stigler and Hiebert (1999) popularised the Japanese Lesson Study and this generated renewed interest in the notion of lesson study and lesson analysis. Over recent years, a number of researchers have used forms of lesson study as part of teachers' professional development (Lewis, 2002). The Hong Kong version of Learning Study is recently developed and introduced to schools (Lo, *et al.,* 2005).

The following is a flow chart of procedures involved in conducting a Learning Study.

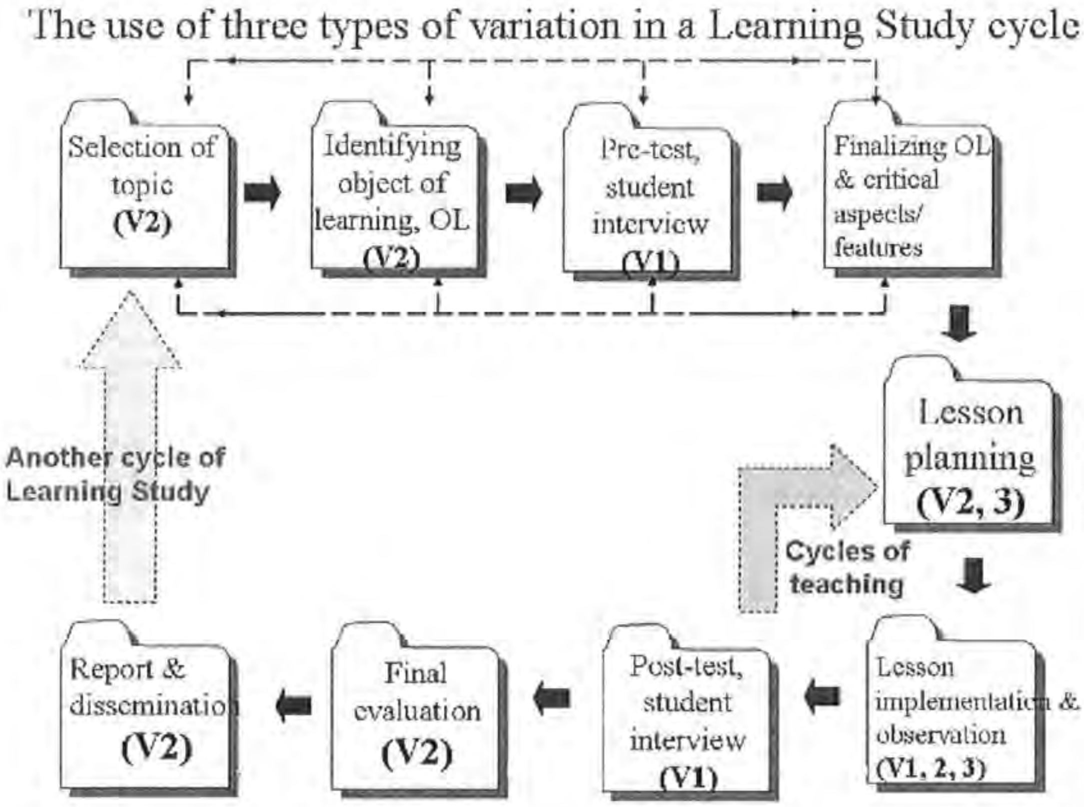


Figure 4.1 Flow chart of Learning Study procedure

A Learning Study group usually comprises two or more teachers teaching the same subject at the same level in each school, plus one or two researchers. These comprise the research team, where each member contributes his/her own expertise and with each member being accorded equal status. Normally each week, as timetabling permits, the group meets for about an hour to work on the research lesson. The whole cycle takes about 10 to 12 weeks/ meetings. A Learning Study goes through a number of steps, though these are not necessarily in a fixed sequence; some steps may occur simultaneously and there may be iteration cycles when certain steps are revisited. Nevertheless, the diagram above provides a summary of the processes normally adopted. These may be described, as follows.

Mains steps in a Learning Study include:

1. *Deciding on the object of learning*

   Starting with an agreed topic area, the group first discusses the object of learning. This is in contrast to what is often normal practice in collaborative lesson planning in Hong Kong, where discussion focuses on the intended lesson sequence and teaching arrangement. Once a provisional object of learning is identified, pupil interviews will be conducted and a pre-test given. This is indicated on the top line of the diagram. The aim of this part of the overall process is to firm up on the final object of learning and critical features. The broken black lines on the diagram indicate, however, that this is seldom a linear process as it might appear from simply following the sequences on the diagram. The process is iterative, with discussion going backwards and forwards as difficulties emerge and new ideas are thrown into the debate. This, as noted above, is a key component of the teachers' professional development process. Eventually, after much debate, a final object of learning and critical features emerges.

2. *Planning and implementing the research lesson*

   Teachers start the detailed planning of the research lesson with a concern for their pupils' difficulties in learning the chosen topic and object of learning, in particular pupils' variations in understanding or their prior knowledge (V1). This information, as already noted is best gathered through pupils' interviews and the pre-test. It is important that the participating teachers can pool their experiences in discussing the object of learning. Information from external research findings are also used in this process and the totality of this information is fed into planning the research lesson. Various "patterns" of variation (Marton, *et al.*, 2003), ways of showing variation, are used in the lesson design to help pupils discern the critical features and focus on them. The sequence of the lesson and the resources to be used are also discussed in detail. As the lesson will be taught by one member of the team, her/his own contribution is crucial. The teacher must feel comfortable with what has been planned. The end result, however, is a lesson plan that is clearly focused on pupils' learning the object of learning. Once finalized, the lesson is taught and observed by the other team members.

3. *Evaluating the research lesson*

   Following the lesson a post-lesson conference is conducted in which the teacher and all those who observed the lesson participate. The lesson is evaluated and revised in the post-lesson conference with reference to comments made after lesson observation, the post-lesson pupils' interview and the post-test analysis. The purpose of all this is to refine the lesson, which is then taught to another class by another teacher and observed by the other members of the research team. The cycle repeats itself until all participating teachers finish teaching. Each lesson is evaluated using the post-test, which is normally the same as the pre-test, with revision made when deemed necessary. The post-lesson interview with pupils is also an important source of data to understand how pupils learnt or did not learn the object of learning. The video-recorded lessons are analysed, focusing on the way the object of learning is enacted by the teacher. A comparative analysis of what happened in the classrooms is conducted focusing on differences witnessed in pupils' learning.

4. *Reporting and dissemination of the research*

   The research results, together with the aims and procedure of the study are shared, first with colleagues in the same school and then publicly with other teachers and researchers. Feedback received will be input into the next cycle of the research lesson.

A detailed timeline for the above steps taken in this study is given in Chapter 5 (Table 5.1, p. 46).

4.4 The methodology as applied to this case

This study followed the main steps listed above and was carried out by the teachers in the school with one researcher from the Hong Kong Institute of Education. As presented here, this study represents a case study in teacher professional development and the enhancement of pupil's learning, the two things being conceived together as part and parcel of the whole case. The school principal scheduled a timeslot every week so that these teachers participated in the study were able to meet with the researcher once a week. The timeline of activities for the project, and a discussion of how these steps were scheduled, are carried over into Chapter 5.

Chapter 5

Learning Study: Design and Data Collection (Stages 1 and 2)

5.1 Research design of the Learning Study case

This school-based study was conducted from 2002 to 2004 and involved four Grade 3 classes (with pupils aged 8-9 years) in a Hong Kong mainstream primary school. In the previous year, a pilot study (based on the same curriculum subject -evaporation and condensation) had been conducted in the same school, involving four classes of the then Grade 3 pupils. The experience and insights obtained from the pilot research lessons greatly influenced the design of the present study, which has the following main characteristics:

1. The overall project was part of the school-based action research initiative, involving a group of four General Studies teachers and a science lecturer from the Hong Kong Institute of Education.

2. The researcher played a dual role, first, as an active researcher participating in the Learning Study process and second, as a researcher in this particular case study concerned with the effectiveness of the Learning Study process in enhancing pupils' learning and teachers' professional development.

3. The teachers were an integral part of the research team, which meant that they not only assisted in the selection, planning, teaching and analysis of the research lesson, they also had a basic grasp of the underlying learning theory.

4. The research used a written test to collect numerical data as a heuristic for identifying the extent of pupil learning in the research lesson.

5. It also used semi-structured interviews with pupils to identify their understanding of the lesson which was then fed back into the subsequent planning process.

6. Interviews were also used with the participating teachers to identify their

understanding of the topic and pupils' learning of science. These were supplemented by teachers' reflections at the end of the project.

5.2 Background of the project school

The school is a mixed subsidized school for pupils of ages 6 to 12 years (Grade 1 to Grade 6), located in a public housing estate in the New Territories of Hong Kong. Pupils at this school represent a broad range of abilities, though the top ability children in the school would not represent the top level of ability in Hong Kong as a whole. They would be closer to the middle range. The research took the form of a Learning Study, carried out with four General Studies teachers and pupils from four classes, namely: Class 3A, 3B, 3C and 3D. The group interview conducted before the project with individual teacher helped the researcher appreciate how the teachers viewed their own teaching of science. A brief background of the four participating teachers is given in the following box.

Teacher A 3A class teacher	A senior teacher having 10 years of teaching experience. She is the curriculum developer of this school and also acted as the coordinator for the school on this project. Though she has taught General Studies over the past years, she admitted that her science background is poor.
Teacher B 3B class teacher	The only male teacher and the only teacher with a science background. Having over 20 years of teaching experience, he was regarded by the other three teachers as the one most knowledgeable in teaching science.
Teacher C 3C class teacher	A young teacher with 3 years of teaching experience. She admitted that her science background is poor and said she relied a lot on the textbook's suggestions to inform her teaching. The textbook provides a standard text following the Hong Kong curriculum.
Teacher D 3D class teacher.	The panel head (Head of Department) of General Studies in this school, having 6 years of teaching experience. She acknowledged that her science background is poor.

Box 5.1 Brief background of the four participating teachers

5.3 The Learning Study time-line and activities in stages 1 and 2

The teaching was conducted by the four teachers, each teaching their own class, with the principal researcher working closely alongside; overseeing the research process and participating in the planning and evaluation of the lessons. Data on the development of children's understanding of the concepts of evaporation and condensation were collected, through interviews and a set of written diagnostic pre- and post-test. Pilot interviews with both Grade 3 and Grade 4 pupils preceded the pre-test. These were used to determine the questions that would be asked in the written test; such that they related to the ability and age levels of the pupils and were attuned to their prior understandings. The written test, in the form of four open-ended questions, was distributed to the 108 children some days before the Learning Study lesson as a pre-test. It was subsequently given again to pupils of these four classes immediately after the Learning Study lesson as a post-test. Pupils' interviews were also conducted directly after the lessons. The interview questions were of a "clinical type", using objects and events as stimuli (Posner and Gertzog, 1982; Bell, *et al.,* 1985). The teachers identified 3 children from each class, providing a sample of the full "ability" range of target pupils. The identification made by the teachers was mainly based on their understanding of their own pupils.

The following table details the overall timeline and the main activities of the research project up until the final reflection and dissemination, which are discussed later in Chapter 6. All the interviews recorded in the table under the headings of "teachers' activities" and "pupils' activities" were conducted by the principal researcher herself. The activities listed in the table, such as the regular meetings, are audio-recorded unless otherwise specified.

Stages	Date	Empowering activities	Teachers' activities	Pupils' activities
Stage 1	Oct 2002 to Feb 2003	Regular meetings before the research lesson A total of 11 meetings of about 1.5 hours each held in school on : - - 8th Oct 2002 - 23rd Oct 2002 - 30th October 2002 - 8th Nov 2002 - 15th Nov 2002 - 29th Nov 2002 - 13th Dec 2002 - 10th Jan 2003 - 24th Jan 2003 - 19th Feb 2003 - 4th Mar 2003	Interview 1 N=4 (at the beginning of the study on 8th Oct 2002)	Pilot Pupil Interviews (23rd Oct 2002) ● Previous Grade 3 pupils N=3 (high, medium and low ability as perceived by the teacher) ● Present Grade 3 pupils, N=3X4 classes (High, medium and low ability as perceived by the teacher)
			● Designing the diagnostic pre-test ● Planning of the lesson. Try-out experiments designed for the lesson	● Draft test paper to 12 randomly selected Grade 3 pupils ● Pre-test (N=108, 29+20+32+27)
Stage 2	Mar 2003	* Pre-lesson conferencing (video-taped) * Lesson observation (video-taped) * Post-lesson conferencing (video-taped)	First cycle: 7th Mar 2003 Class: 3C Lesson observed by team members (video-taped)	● Post-test after the lesson (N=29) ● Pupil interview (N=3) (video-taped)
			Second cycle: 11th Mar 2003 Class: 3B Lesson observed by team members (video-taped)	● Post-test after the lesson (N=20) ● Pupil interviews (N=3) (video-taped)

		***(Note: the three procedures listed above were repeated in each of the four cycles.)**	Third cycle: 13th Mar 2003 Class: 3D Lesson observed by team members (video-taped)	● Post-test after the lesson (N=32) ● Pupil interviews (N=3) (video-taped)
			Fourth cycle: 13th Mar 2003 Class: 3A Lesson observed by team members (video-taped)	● Post-test after the lesson (N=27)) ● Pupil interviews (N=3) (video-taped)
	Apr 2003	Evaluation of the study	● Evaluation meeting (20th Mar 2003) ● Teacher Interview (N=4) (10th Apr 2003)	

Table 5.1 The timeline and activities of the research project in stages 1 and 2.

5.4 The Learning Study process

5.4.1 Stage 1

5.4.1.1 Teachers' discussion of the object of learning

As noted in the previous chapter, an important feature of the Learning Study model is the identification of the "object of learning" for any given lesson. Specifying the object of learning involves identifying two kinds of variation. The first is variation in pupils' understandings and pre-conceptualisations that they will bring to the study of the object of learning. This is referred to as Variation 1 (V1). The notion that children's preconceptions and misconceptions should provide a starting point when planning a science lesson has long been emphasised by constructivists (Driver, *et al.*, 1989). The Learning Study model also encourages teachers to start thinking about the lesson with this variable in mind. The second variation is in teachers' understanding of the object of learning, including their past experience of teaching the topic. This is known as Variation 2 (V2). Recognition of this variable provides an important opportunity for professional dialogue, such that teachers can learn from each other and realise the multiple ways of dealing with the same topic. Both variations give rise to the kind of reflection on practice that can contribute to the teachers becoming action researchers into their own practices. The two forms of variation are interwoven with each other at all stages of the Learning Study.

At the start of the study (Stage 1), the four teachers in this school had expressed concerns over pupils' difficulties in learning "the formation of mist and fog" which is an item on the science syllabus following the "change of state of water". Teachers were asked to begin their discussion by sharing their previous experiences of teaching the change of state of water, which they thought was easy compared with teaching "mist, dew and fog". The assumptions and beliefs held by teachers clearly influence their practices in the classroom, with the main tendency of the group being to maintain the status quo by reverting back to the textbook. In the first two meetings among the eleven, teachers expressed their opinions and assumptions. An extract of part of the discussions is presented below:

TB : *I don't think "the change of state of water" is a difficult topic.*

TA : *Yes, children can easily encounter the three states of water in their daily lives. Do we really need three to four months to work on this lesson on change of state?*

TC : *I always refer to the textbook for the experiments; I have no problem teaching this lesson.*

TD : *Not only the pictures in the textbook, I allow them to take out some ice from the freezer and watch it melt.*

TB : *If time allowed, I will boil a kettle of water in class and let them see the steam. I will also ask a pupil to come out and condense the steam back to water with a piece of glass. A very smooth lesson!*

TA : *I do that too in the lesson.*

In sharing their past practice of teaching the topic, the teachers concluded that showing the class the experiments suggested in the textbook was the right way to proceed. As noted above, an understanding of the nature of science is problematic for at least three of the four members of this group of teachers. From what they said, it seemed that their preferred object of learning for this lesson was for pupils to remember the four scientific terms: melting, boiling, freezing and condensation. For some reason, the process of evaporation is not covered in the textbook when dealing with this topic, and, as the teachers rely on the textbook for their choice of content, they had not previously taught that concept.

5.4.1.2 Pilot pupil interviews

In order to help teachers focus on the learning difficulties of their pupils and to prepare the diagnostic pre-test, three Grade 3 children covering a broad range of ability (high, medium and low as perceived by their teachers), were interviewed class by class by the principal researcher to find out their understanding of the phenomenon before they learnt the concepts of evaporation and condensation. Moreover, a second sample of three children from the previous year's Grade 3 class (now Grade 4) was interviewed in order to ascertain whether their understanding of the phenomena was materially different from those of the present cohort. These were semi-structured group interviews with two key questions being asked. Prompting questions assisted the flow of the discussion. The findings of the Grade 3 pupils, which will be discussed in the following paragraph, showed that they could not offer a scientific explanation to the two phenomena used in the interview. The findings of the Grade 4 pupils, however, though they had learnt the concepts in the previous year, showed there was no deep learning taken place. This group of pupils were only able to provide terms like "boiling" or "condensation" in the interview. No further explanation was provided about the two phenomena provided in the interview. The result of these interviews helped to indicate the potential starting point of the pupils.

Questions related to boiling of water and freezing of ice were asked. Among these, there were two key questions asked, which were identified in the literature review, in the research conducted by Bar and Galili (1994). These were:

1. When the laundry dries up, what happens to the water? Where has it gone?
2. Why are there water-drops on the can of coca-cola taken out from the refrigerator?

The first question is illustrated in the conversation with one group of three pupils of Grade 3 pupils from class A, who had not learnt the concept of evaporation, below:

R — *Principal researcher*

PA1 — *low ability pupil*
PA2 — *medium ability pupil*
PA3 — *high ability pupil*

PA1 : *It drips dry.*
R : *What does that mean?*
PA1 : *All the water falls to the ground and so it dries.*
R : *What do the others think?*
PA2 : *I think some of the water goes to the sun.*
R : *What then?*
PA2 : *It goes up and becomes cloud.*
PA3 : *Yes, it becomes cloud.*
PA2 : *I think the water becomes air.*
R : *Can you explain further?*
PA3 : *It changes to air...may be oxygen.*
PA2 : *Air can also vaporise it.*
R : *How?*
PA3 : *Because the air is hot.*

The findings from the pupils' interview were similar to findings in some overseas research. As noted earlier in Chapter 2, the research carried out by Bar and Galili (1994), for example, reported a sequence of four views gathered after interviewing children from 6 to 15. These were:

(A) Water disappears.

(B) Water was absorbed in the floor (or/and ground).

(C) The water "evaporates", meaning it is now unseen and being transferred into an alternative location or medium, etc.: "somewhat in the "sky", "sun", "ceiling", "air", or "clouds".

(D) The water changes into vapour, as small (commonly unseen) droplets, dispersed in the air, or water is transformed into air.

Their study reflects that younger children tends to hold views A and B, while at age 11 to 12, only about 50% can give view C and only 10% can give view D which is closest to the scientific view. From our interviews with Grade 3 pupils, aged eight to nine, four pupils thought that water would inevitably drip dry from the laundry which was perceptible, very close to view B with no concept of conservation. Another seven pupils tended to associate "drying up" with the sun and the formation of the cloud, close to view C. This gave the team a preliminary picture of the pupils' understanding of evaporation at room temperature. Among the twelve pupils interviewed (3 pupils from each of the four classes), just one pupil approached view D; PA3 in the above transcription, which is the one closest to the scientific view. Yet, there is still a gap between PA3's view and the scientific view in that he thought the water changed to air, might be oxygen, but not as vapour existing in air.

The second question is illustrated below in the conversation with another group of three pupils of Grade 3 from class 3D, again who had not learnt the concept of condensation, below:

R	—	*Principal researcher*
PD1	—	*low ability pupil*
PD2	—	*medium ability pupil*
PD3	—	high ability pupil

PD3	:	*The water-drops were from the refrigerator.*
PD2	:	*Yes, I think so.*
PD1	:	*But I think it's leaked from the can.*
R	:	*But it's colourless, not like the coca-cola.*
PD1	:	*It should be like that. Because it's cold. Cold will be like that. This morning my mother gave me a bottle of cold water taken out from the fridge, it also leaked.*

This finding is similar to that of Johnson (1998) and Paik, *et al.* (2004) in that the pupils have no concept of change of state of water in relation to condensation. This is a more difficult concept than evaporation. Their conclusion that children's conception of phenomena involving the invisible state of water is problematic. Tytler (2000) echoes this same point in his study. The following points can be summarized from these two group pupil interviews:

1. They tended to relate evaporation to an obvious heat source such as the sun.

2. The concept of water existing in gaseous state in air was absent or ambiguous.

3. They had not got the concept of condensation of atmospheric water vapour on a relatively cooler object at room temperature.

4. The interchange of the use of terms like vapour, air, steam and gas is common.

5. The pupils can give some anecdotes to support their explanation (the bottle from the fridge).

6. The pupils had no concept of conservation of matter, which may be important before learning the change of state of matter.

5.4.1.3 Specifying the object of learning

Interviews, conducted with the sample (three pupils) from the previous year's Grade 3 pupils, indicated that on the whole pupils had no difficulty in understanding the concepts of water changing to solid ice when freezing, and returning to liquid again at room temperature. The concept on the gaseous state of water, however, was found to be very problematic. Pupils thought that when water disappeared during boiling, it went directly up to the sky and became clouds and was stored there. When the puddle of water on the playground disappeared, two out of three thought it had gone to the sun. One said that the water disappeared because it changed to air. When water drops appeared on the outside of a cold coca-cola can when brought from a refrigerator, one pupil, who was regarded as low-ability, thought that the droplets were formed as water leaked from the coca-cola in the can. The other two pupils, though realising that the phenomenon had something to do with the coldness of the can, were unable to offer possible reasons other than repeating that the refrigerator was cold. Teachers realised from these responses that what they had taught in the previous year about the change of state of water was not able to help the pupils understand the phenomena of the formation of mist and fog. The missing element was that the pupils (and teachers) did not appreciate the importance of the notion that water vapour is held invisibly in the air. They began to see how research (Bar and Galili, 1994; Johnson, 1998; Tytler, 2000) could inform their work in the classroom and were amazed to find that children of different nations held similar views at more or less the same age regarding the same phenomenon. The impact of this realisation was very evident in the discussion following the interviews with the previous year's Grade 3 children. It is transcribed below:

TD : *I thought I have made myself very clear in the lesson, but may be I have not touched on the concept.*

TC : *I have never thought of the need to go further after showing them what the three states are. In fact, it's my question too.........where has the water gone after it disappears? I have never thought of this as important. I think the key thing to understand this is water continues to be water, though it has changed state.*

(Note: She's the young teacher who had three years of teaching experience)

R : *That's a very good point, thanks to TC who reminds us of this. I think we have to make it explicit in the lesson. We have to remember this point in the design of the lesson.*

TA : *To me, science teaching is always difficult; talking to my pupils is a wonderful experience. I am happy to find out how they think, and how I think too.*

TB : *After telling the class the facts, they should be able to remember......... (utterance) may be they have forgotten.*

(Note: He's the expert, the only one among the four who came from a science background and viewed himself as a good science teacher.)

TD : *I am a learner in the process too. I am able to realize that water has not changed to air...it's confusing to say that it has changed to gas. ....but it should be a gaseous state, right?*

(Note: in Chinese, air and gas bear the same translation)

A full transcription of the above discussion in the regular meeting can be found in Appendix 1 (p.138). The extracts illustrate two points regarding the teachers' past teaching:

1. The differences in their acceptance of their own weakness as an effective science teacher. Teacher A, C and D, as I can see at the start of the study, were more prepared to admit to this. Teacher C, though young in her teaching experience,

was smart in identifying the critical feature in helping the pupils to learn the concept of evaporation. Teacher B, at this stage, still clings to his view of learning, didactic and rote learning as the most important.

2. The discussions about their weaknesses in the teaching of science were not perceived as a threat by the teachers. Rather, it was very encouraging to see a genuine professional dialogue was in process.

It was during the initial eleven meetings (Stage 1) that teachers were provided with the opportunities to re-examine and clarify their own concepts on the chosen topic. Selected research papers on children' ideas on the related topics (Bar and Galili, 1994; Johnson, 1998a, 1998b; Tytler, 2000), presented by the principal researcher, proved to be crucial in opening up the teachers' understanding of how children think in regard to the change of state of water. Teachers became sensitised to the fact that many of their pupils were probably unable to learn the concepts of mist and fog, given the way that the change of state of water had previously been taught. It was forcefully brought home to them that teaching does not inevitably lead to learning. The traditional approach to teaching this topic, relying entirely on the content of the textbook, is problematic and should gradually be abandoned; being replaced by more open-minded thinking about the content of the classroom curriculum. The pupil interviews provided evidence for teachers of the need to carefully select a *worthwhile* object of learning for their lesson, rather than simply implement the given curriculum.

Moreover, the overseas research findings regarding children's conceptualisation and misconceptualisation of these phenomena alerted the four teachers to the fact that they had overlooked the teaching of evaporation and condensation, and they began to see more clearly the importance of relating their teaching to their pupils' difficulties in this regard. The team decided to focus the research lesson on the state of water during evaporation and its reappearance on a cooler surface during condensation at room temperature. As a result of this reflective interaction between teachers, the tentative object of learning that finally emerged was:

The interconnectedness of evaporation and condensation of water at room temperature.

Following the pupils interviews, the team devised a pre-test that focused on the two concepts of evaporation and condensation. The result of the pre-test for the four classes on the concept of evaporation and condensation (given below in Tables 5.5 and 5.8) confirmed the findings derived from the interviews; that there was much confusion in the minds of the pupils. However, an arguably more important finding emerged from the team discussions; it became increasingly evident, though not explicitly stated, that the teachers were also unsure about the two selected concepts. They did not *realise* that water disappeared into air as vapour during evaporation. They often stopped the discussion when referring to the idea that water has turned to vapour, without ever asking where it goes. They also did not appreciate that condensation is a form of change of state with the vapour coming from the surrounding air. They were therefore in no position to teach the class that condensation is the reappearance of water that already exists in the air.

5.4.1.4 Identifying the critical features

In addition to clearly and precisely specifying the object of learning, the Learning Study model emphasises the need to identify the critical features, necessary to achieve the intended learning. As discussed earlier, an understanding of the critical features is a pre-requisite to successful learning, for if these are not understood, or are misunderstood, children will not fully discern the object of learning. As the discussion proceeded, it became clear to the team that for pupils to develop the concept of condensation and evaporation below boiling point, the existence of atmospheric water vapour in the air is most critical. Therefore, special attention had to be given to the *imperceptible* state of water, for that seemed to be the greatest stumbling block that the pupils have to jump if they are to understand evaporation and condensation. Here "evaporation" refers to evaporation at room temperature, without an "obvious" source of energy, and condensation refers to condensation of atmospheric water vapour on a cooler surface at room temperature. These phenomena are distinct from boiling and condensation of water at boiling point. With these considerations in mind and given the data collected from the pupil interviews, the team tentatively identified the following three *critical features (CF)* related to the object of learning, though it was understood by all that these would be confirmed or modified after the analysis of the pre-test. Tentatively, the three critical features related to the chosen object of learning, were:

1. The loss of liquid water to the surrounding air indicates the occurrence of evaporation below boiling point.

2. Water evaporation may take place at any temperature below boiling point, without an obvious heat source.

3. Atmospheric water vapour is invisible. The disappearing of water during evaporation means that liquid water has changed to a gaseous state and existed in air. The reappearance of water drops on a relative cooler surface indicates the occurrence of condensation.

As a result of the lengthy discussions it was firmly appreciated by the whole team that developing the concept of condensation and evaporation below boiling point, is a pre-requisite for pupils to understand the phenomena on the formation of cloud, mist and fog. Only when pupils realise that atmospheric water vapour exists in the air and evaporation and condensation happen in nature, will the formation of cloud, mist and fog cease to be a problem for their understanding. It was therefore tentatively decided that the design of the lesson would focus on helping pupils to discern these three critical features, and that the teachers would be aware of the importance of highlighting them during their teaching.

5.4.1.5 Pre-test design

Within the framework of Learning Study, various sources including pupil interviews, pre-lesson written test and teachers' past experiences in teaching this object of learning are used to identify variations in pupils' different understandings. Based on the work of Bar and Galili (1994), Johnson (1998) and Tytler (2000), the team spent several meetings discussing the preliminary design of the test items for diagnosing the pupils' conceptual understanding. Teachers also made use of insights from the group pupil interviews in the drafting process, incorporating pupils' perceived difficulties into the test paper.

The pilot test paper (Appendix 2) was then administrated to a group of twelve Grade 3 pupils, chosen randomly from the four participating classes, by the principal researcher. On the basis of the pilot test results, appropriate revisions were made to ensure that the scenarios in the paper covered different aspects of evaporation and condensation that closely related to the pupils' everyday lives. Wordings and expressions on the test items were modified as a result of the pilot test. The revisions were:

1. Reduce the number of questions from 6 to 4, omitting one on evaporation and one on condensation. The one on evaporation was about the drying up of the blackboard after wiping. Teachers thought that pupils might not have such experience since whiteboards were used now. The one on condensation (the white fume from the freezer) was found to be too challenging to Grade 3 pupils. In doing this, we could also reduce the time pupils required to spend on answering the questions.

2. In order to focus our analysis of pupil's explanation of the phenomenon observed, the principal researcher also suggested modifying the question format in the pre-test as follows:

   In the pilot test:

   "There is a puddle of water on the playground. After sometime, what will happen to it? Why?"

   (Two questions were asked. The first question may affect the analysis of the answer for the second question, which is the focus of the study)

   In the pre-test:

   "There is a puddle of water on the playground. After sometime, the puddle disappears. Why?"

   (One question was asked. Pupils were only requested to provide their explanation for the given phenomenon.)

Reference was made to Tytler and Johnson's studies in drawing up the test items. The revised written test was composed of four questions (refer to Table 5.2 below and Appendix 3), aimed at assessing pupils' conceptual understanding of evaporation and condensation in relation to the *disappearance and reappearance of* water under different everyday scenarios. Previous studies (Bar and Galili, 1994; Tytler, 2000) showed that some children would have no difficulties after the lesson in using terms such as evaporation to describe why water disappeared from a particular scenario or using the term condensation to report on the reappearance of water in a particular instance. However, as indicated in these studies, pupils in fact held different views of evaporation or condensation of water, though they used the same terminology. The purposes of these test items were twofold. Firstly, they were used to identify whether or not pupils in the school experienced similar conceptual difficulties, as indicated in other similar studies and secondly, to inform the effectiveness of pedagogy designed to solve problems identified from pupils' answers.

The four questions (in Cantonese) asked in the interview and the pre-test (in translation) were:

1. There is a puddle of water on the playground. After a while, the puddle disappears. Why?

2. We hang wet laundry under the sun. After a while, the laundry dries up. Why?

3. We take a can of soft drink from the fridge. After a while, there are water droplets on the surface of the can. Why?

4. We put a lid on a mug of hot water. After a while, there are water droplets on the surface of the lid. Why?

As mentioned earlier, the pre-test will also be used as the post-test after the research lesson is taught. The test items can also be found in Appendix 3. The four pictures in Table 5.2 were provided on the screen projected from the computer as the pre-test was held.

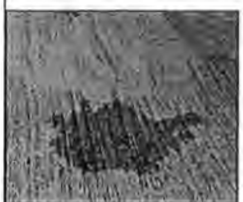
Disappearance of water (evaporation)	Reappearance of water (Condensation)
 There is a puddle of water on the playground. After a while, the puddle disappears. Why?	 We take a can of soft drink from the fridge. After a while, there are water droplets on the surface of the can. Why?
 We hang wet laundry under the sun. After a while, the laundry dries up. Why?	 We put a lid on a mug of hot water. After a while, there are water droplets on the surface of the lid. Why?

Table 5.2 The four questions in the pre-test

5.4.1.6 Pre-test analysis

5.4.1.6.1 Categories employed for analysing pre-test and post-test answers regarding the concept of evaporation

The categories used for both pre-test and post-test analysis were the same. They were derived initially from insights gained from previous researches by Bar and Galili (1994) and Johnson (1998), which were considered by the teachers in their discussion, as they reflected on pupils' answers to questions in their preliminary interviews. The categories were designed to cover the different levels of understanding from no understanding to full, scientific understanding of the concept. As a result of detailed discussion, the team concluded that the range could be covered using four categories. Nevertheless, the researcher was mindful that with all such categories there is an issue of interpretation when applying what a pupil has actually written in a test answer to the table of categories.

The four categories that were decided on are given below in Table 5.3 for the concept of evaporation.

Code	Category description
E1	Intuitive answers; fail to give logical reasoning towards the disappearance of water.
E2	Water disappears because it is being absorbed by a physical object (the surface it attaches to). e.g., Water being absorbed by the ground- attempted to report on the fate of water but fail to see water as vapour.
E3	Water disappeared because an energy source such as sun or wind is there to *remove* them from *attaching* to an object. Water becomes the cloud.
E4	Water disappears because it has undergone the process of evaporation, which causes it to change into vapour state and moves into the surrounding air. Answers are of two kinds: a. can provide the term "evaporation" correctly; b. can provide further justifying elaboration.

Table 5.3 The four categories for responses to questions on evaporation

5.4.1.6.2 Responses to questions on evaporation

Accurately categorising pupils' responses proved to be very challenging for the team as it was not always clear how their answers corresponded with the table. There were clear-cut cases such as "water is absorbed by the ground" which clearly comes into Category E2. Nevertheless, even though pupils were encouraged to supplement their answers with drawings, sometimes it was not easy to analyse pupils' responses and classify them according to the precise categories. For example, it was decided by the team that a response which suggested that water disappears "because it is hot" without mentioning the source of heat was put under E3, as the team thought that the pupil was able to relate the importance of an unobvious heat source in the process. Responses like "air can evaporate water" were included in Category E4a, on the ground that, to these young children, air may mean wind or heat. There was evidence in the pupil interview that children think that some heat source must be there in the air or in the surrounding for water to disappear. The teachers also identified a major difficulty in dealing with E4 responses. When a pupil gave a response like "evaporation" without further elaboration with another one like "water has disappeared because it has change state to vapour and cannot be seen", definitely represents two levels of understanding. The teachers suggested modifying Category E4 to E4a and E4b (refer to Table 5.4 for illustration) to find out the number of pupils who can arrive at a higher level of understanding and can tell the fate of water besides providing the scientific term – evaporation. Examples of pupils' responses to the fate of evaporation for the two related questions in each category are given below:

Categories	**Example of pupil's response**
E1	• No water, it should be like that; • Changes to muddy colour; • Dry up, because has been there too long; • Don't know why.
E2	• Water will dry up because the ground will absorb water; • The laundry drips dry.
E3	• The sun absorbs the water, I have seen it before; • Because the sun is hot; • Because there is wind. • The function of the sun can dry the laundry.
E4a	• Water has evaporated; • Evaporation (just the term provided).
E4b	• Water has changed to vapour and gone into air; • Water has evaporated and become vapour that cannot be seen.

Table 5.4 Examples of pupils' responses (given in Chinese) to questions on evaporation

The practice of going through pupils' responses in the pre-test paper with the teachers proved to be very useful in two ways. Firstly, teachers gained great insights in understanding their own pupils' ways of thinking. When teachers have that understanding they can gear their teaching to the difficulties of their pupils and thus help them learn. Secondly, teachers began to regard themselves as researchers and establish the practice and attitudes of gathering evidence to support their actions.

TB : *Pupils' drawings are amazing; it gives me a better picture of how pupils think.*

TA : *Pupils' responses are very similar to overseas work. I am glad that my work can be informed by research.*

R : *Have you ever done this before in your teaching?*

TC : *Never dream of doing so, though we have the theoretical part in the teacher education, but simply put it aside.*

TD : *Because we think this is not possible for us as teachers to do so, but now we are really looking into some data and this helps us to set the direction for our teaching.*

Up to this point, the precise object of learning has been identified along with the critical features (5.3.1.3). As described in Chapter 4 on the Learning Study framework, the eventual design of the research lesson critically depends on the pupils' responses to the questions in the pre-test. An analysis of the responses of pupils of the classes is given below. Table 5.5 below relates to the two questions on evaporation, Table 5.6 to the two questions on condensation. In both tables, the sequences of the lesson cycle are given in terms of the class name: 3C, 3B, 3D and 3A.

Categories		3C (N=29)		3B (N=20)		3D (N=32)		3A (N=27)	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
E1		14	5	10	8	4	0	15	4
E2		3	2	0	0	0	0	0	2
E3		11	18	10	12	24	31	12	20
E4	E4a	1	4	0	0	4	1	0	1
	E4b	0	0	0	0	0	0	0	0

Table 5.5 Pupils' responses to questions 1 and 2 on evaporation (pre-test).

The team read through the written responses and found, as in other such studies, that this group of age 9 children did not possess the skills of clearly expressing written thoughts on paper. The team relied heavily on the pictures drawn by the pupils to illuminate their thinking. The following findings were very important in helping the team to focus on pupils' difficulties in the design of the research lesson.

1. The tendency of pupils to give irrelevant responses (Category E1) was more apparent in the case of the puddle of water than the wet laundry questions. This is an interesting difference and might reflect the different nature of the context when drying laundry might be a more familiar, everyday experience than puddle drying. This may reflect the fact that opportunities for children in Hong Kong to play outdoors are far less than in some overseas countries, like Australia and Britain for example. However, wet laundry hanging to dry in the flat is common in Hong Kong, and is thus part of the children's daily experience.

2. The frequencies of response for both questions, across the four classes in Category E2, were few. About 3 pupils in class 3C suggested that the water has been absorbed into the ground with the puddle and 2 pupils each in class 3C and 3A held the same view that the laundry drips dry. These are in fact accurate observations, but pupils failed to provide a complete explanation for the fate of the water. These views are in line with overseas studies.

3. The view that the loss of water is something to do with the sun (e.g. the sun *sucks* up the water), the wind or the air (Category E3) is prevalent among this group of pupils for both questions. In class 3D, all pupils' responses achieving Category E3 to question 2. Though both the puddle of water and the wet laundry relate to outdoor contexts, the view that wet laundry being related to the sun (pupils used expressions like, *sucked up by the sun, run to the sun or being drunk by the sun)* is more prevalent and seemed to be better explained than in the case of the puddle, though how the sun could aid the evaporation of water to vapour was not mentioned. An obvious reason is to do with the wording of question 2 when it said that the wet laundry was put *under the sun*. The team was unaware of the importance of "neutral ground" (Johnson and Gott, 1996) and the effect of putting

words into pupils' mouth is obvious with this case.

4. The term "evaporation" is mentioned by a few pupils without further elaboration on the fate of water (ranging from 1 to 4 pupils for both questions about evaporation). This might be the result of reading from books. No pupils achieved Category E4b.

5. No pupil mentioned that the water has changed state to vapour in the context of the puddle or the wet laundry in the pre-test. This finding corresponds to overseas finding with regard to this age group of children.

6. Moreover, it appeared to pupils that water seemingly ceased to exist in the air in both cases, as they could hardly explain what happens to liquid water when it evaporated.

The team concluded that most pupils did not have a thorough understanding of what constitutes the phenomenon of evaporation. They concluded that "when water disappears, it continues to be water but in the gaseous state" is a crucial notion if pupils are to develop the concept of evaporation. A number of studies have highlighted the great difficulties experienced by young children regarding this notion. Lee, *et al.* (1993) report:

> *The most common problem involved the existence of invisible (water) vapour in the air, as shown in the examples above. In their explanations of changes of state involving gases, many students focused on 'air', which might largely be due to their failure to understand the existence of water vapour. In fact, understanding conservation of matter, particularly involving water vapour in air, turned out to be the most difficult of all macroscopic conceptions for students in both years.* (p. 264)

Another important aspect of evaporation is that water can change to a vaporous state in the process of evaporation, without an obvious heat source. As noted earlier, these two aspects thus became the critical features of the selected object of learning. The actual design of the lesson, which makes use of the patterns of variation to help pupils discern these critical features, will be discussed later in section 5.4.1.7 of this chapter.

5.4.1.6.3 Categories employed for analysing pre-test and post-test answers regarding the concept of condensation

The other two questions in the pre-test related to the concept of condensation. Again four categories were developed to classify pupils' responses. References were again made to the work done by Johnson (1998) in interpreting the responses provided by pupils in the test.

Code	Category description
C1	Irrelevant answers; fail to give logical reason for the phenomenon.
C2	Source of water unknown; may be from the can or from the fridge. Associate it with the lid but don't know why.
C3	Temperature different, something is cold/or cooler or the air is warmer. Can tell the source of water, e.g. steam from the hot water.
C4	Vapour from the air can appear as water on a cooler surface. Answers are of two kinds: a. can provide the term "condensation" correctly b. can provide further justifying elaboration.

Table 5.6 The four categories for responses to questions on condensation

After going over all the written responses, the four teachers again felt that it would be more appropriate to split Category C4 to C4a and C4b (Table 5.6), as in the case of evaporation. These four categories were used for both pre and post-test. Some examples are presented in Table 5.7.

Categories		Examples of pupils' responses
C1		• The fridge has air • Don't know • There is water
C2		• It's from the fridge • It's in the fridge for a long time • It's the ice from the fridge • Because there is the lid stops the steam
C3		• Because the fridge is cold/the lid is cooler • The outside air is hotter than the fridge • Because hot +cold • The fridge has made the can cold • Because the can/lid is cold • Because there is water vapour/steam • Steam rising up to meet the lid
C4	C4a	• The term 'condensation' is given • Just mention the water vapour meets something and condenses to water. • The air is met by the cold can, then water drops appear.
	C4b	• Water vapour from air/from the hot water condenses on a cooler can/on the cooler lid. • The 'white fume' from the water meets the cooler lid and condenses to water drops.

Table 5.7 Examples of pupils' responses (given in Chinese) to questions on condensation

5.4.1.6.4 Responses to questions on condensation

Pupils' responses of the two questions about condensation were analysed using the categories listed in Table 5.7. The following table (Table 5.8) provides a summary of the findings.

Categories		3C (N=29)		3B (N=20)		3D (N=32)		3A (N=27)	
		Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4
C1		11	8	10	6	11	6	15	16
C2		3	6	3	2	7	6	4	4
C3		14	13	7	12	14	20	8	7
C4	C4a	1	2	0	0	0	0	0	0
	C4b	0	0	0	0	0	0	0	0

Table 5.8 Pupils' responses to question 3 and question 4 on condensation (pre-test)

Going through the responses to the questions on condensation provided a lot of insight for the teachers. On the whole, for this group of pupils, the understanding of the concept of condensation is more problematic than the concept of evaporation. The following points are worth noting:

1. For the two questions on condensation, the team found that a high proportion of pupils' responses were in Category C1, where pupils provided irrelevant answers or left it blank. One of the teachers (TA) suggested that this might be related to the imperceptible state of water, a process that makes it a less familiar phenomenon.

2. Responses like 'it's from the fridge' represent recognition of temperature playing a part in the process and, this also seems to be recognised in the answer about the lid, where it is assumed to be at a different temperature from the hot water in the mug.

3. In understanding the concept of condensation, two things are crucial, one is the source of the invisible vapour and the second is the existence of a cooler agent for it to reappear. The team thought that the two contexts provided in the pre-test must have created certain difficulty for this group of age 9 pupils. Different contexts cued different images for these two questions on condensation. The differences in temperature between the cold can and its surroundings is more observable than the hot water and the lid, so response like "the fridge is cold" or 'the can is cold' is more prevalent than the response "the lid is cooler" which were

included in Category C3. It is interesting to note that with the case of the mug of hot water, a number of responses, which we classified as in Category C3, relate the water on the lid to the steam rising from the hot water like "there is steam rising up", or "steam rising up to meet the lid", though a complete explanation was not provided. No pupil managed to point out that the water on the cold can is from the surrounding air.

4. Only a few pupils (2 in class 3C) used the scientific term "condensation" without further elaboration. This is distinctively different from evaporation phenomenon, where the phenomenon and the term seem to be more familiar in their daily encounters.

5. No pupil could elaborate further on how the appearance of water on the cold can and lid, resulting from the gaseous state of water, whether from the surrounding air or from the rising steam, changes back to liquid water on a cooler surface. Technically, the rising steam has already condensed back to liquid water, though given the starting point of both pupils and the teachers; this is a fine point to emphasis.

The analysis of the pre-test helped the teachers better understand pupils' various ways of conceptualization, and contributed to the identification of the critical features in helping the pupils to develop the targeted concepts. The three critical features identified earlier were then confirmed, prior to the lesson-planning stage. Moreover, the same test as the pre-test consisting of the same four questions was administered to each class right after each cycle as post-test. The team made no changes to the questions of the test, to allow for a more accurate comparison of pupils' view on the same phenomenon.

5.4.1.7 Design of the lesson – Planning the lesson, making use of the patterns of variation

For many teachers in Hong Kong, Learning Study provides a whole new angle on lesson planning, presenting a challenge for the teachers. The practice of teachers jointly planning a lesson has been incorporated into Hong Kong schools for a few years.

However, their main focus is the discussion on the teaching strategies. It is not usual to talk about what the object of learning for any particular lesson should be. What has been stated in the textbook provides what should be taught. Most of the time, the discussion will be on the logistic arrangement of the lesson and division of labour among teachers. With the Variation Theory as the framework in conducting Learning Study, the team's discussion mainly focused on the object of learning, which, as just described, was finally decided based upon the information solicited from the pupils' interviews and the result of the pre-test. The team then proceeded to consider planning the research lesson with the aim of providing pupils with a deeper conceptual understanding of the object of learning.

According to Marton (1997), if learning is to take place, there must be learning of "something" and that "something", the object of learning, must be discerned through the identification of its related critical features. The teaching act should direct pupils' attention towards the critical features if they are to discern the object of learning. Anything else that might distract pupils from learning the critical features should be put aside or kept in the background.

The organisation of the lesson was discussed in great detail. However, all four teachers were rather uncomfortable with allowing pupils to take a more active role in their own learning. When the team came to the discussion on how to make use of the pattern of variation as a pedagogical tool, in designing the learning activities, there was a lot of negotiation and persuasion taking place as part of the fruitful exchanges. Teachers, on the whole, wanted to have control over pupils by restricting them to respond to a well-structured worksheet. They had two concerns, firstly the abilities of their pupils to make accurate records of their observations and to provide explanations of the case. Secondly they were uncomfortable in opening up the space for pupils to participate in the lesson, having to face the challenge of the great variety of questions that might be raised by the pupils. The lack of self-confidence in teaching science and the concerns of the teachers regarding their own comprehension of the phenomena is of course understandable, and raises questions about General Studies as a subject and the initial training of teachers in Hong Kong; issues that will be considered again in Chapter 7.

After some discussion and encouragement, the teachers in this team were willing to give it a try.

> *TD* : *I am not good at science, I am afraid I cannot answer pupils' questions.*
>
> *TB* : *May be we can have a rehearsal of the question asked. This can help us.*
>
> *TA* : *My class is the weakest; they may not have many questions to ask.*
>
> *TC* : *I will try. You will all see how I have done it and learn from it, as I am the first one to teach the research lesson!*

It was important that every team member took ownership of the lesson as a collaborative effort; with each teacher bearing collaborative responsibly for the success of the lesson. In designing the activities of the lesson, the following considerations were discussed:

1. Since the teachers wanted to compare the results of boiling to those of evaporation, some preparatory work had to be done before the lesson to facilitate the discussion. A test tube of 5 ml of water was placed in the classroom three days before the teaching of the research lesson.

2. Pupils were also asked to perform a simple experiment at home by putting one spoonful of water on a small plate and put it away from the window for three days. A record sheet was provided for them to make record of what happened to the water.

3. Evaporation of water to a gaseous vapour forming part of the air has to be established before the notion of condensation. It was hoped that the connection between the disappearing of water to the surrounding air and the re-appearing of water from the surrounding air could thus be made.

4. To prevent pupils from thinking that there might be leakage from the coca-cola can taken out from the fridge, two identical metallic ladles were instead used for experiment 3 on condensation. It also minimises the chance of pupils memorising the findings in class, to be repeated in their post-test.

5. It was suggested that a cooling box with ice be taken into the classroom for experiment 3 on condensation, so that the ladle could be cooled enough to show the result of condensation.

The experiments were designed in such a way that pupils could compare and contrast the results to make correlations between cause and effect and at the end could generalise the conclusion. The intention was to provide opportunities for pupils to make discernments. The following tables illustrate examples of how the pattern of variation was used to guide the design of the lesson.

Activity 1 (Teacher demonstration)	**Discernment**	**Not varied**	**Varied**
1. Boil a test tube of 5ml of water, level marked in red before and after boiling. 2. Compare the level of water after boiling for three minutes with that placed in the classroom for three days. 3. Group discussion and reporting back	• The loss of liquid water indicates the occurrence of evaporation. • The liquid water has changed form and gone to the surrounding air. • Water evaporation may take place even without an obvious heat source.	• 5 ml of water in two test-tubes	• Temperature (one at room temperature and one at boiling point); • Duration (one is three days and the other is around five minutes)

Table 5.9 Pattern of variation used to serve the function of fusion in dealing with loss of liquid water during evaporation

Activity 2 (Class discussion)	Discernment	Not varied	Varied
1. Report the observation of the result with the water put on the plate at home three days ago. 2. Compare the result with the test tube of water put in the classroom three days ago. 3. Class discussion.	• Liquid water can change to vapour at room temperature that can occur everywhere.	• Temperature (room temperature) • Duration (three days)	• Container (test-tube and the small plate) • Environment (in school and at home)

Table 5.10 Pattern of variation used to serve the function of generalisation in dealing with the nature of evaporation occurs everywhere

Activity 3 (Teacher demonstration)	Discernment	Not varied	Varied
1. One ladle (A) put in the ice box before the lesson. 2. One ladle (B) placed on the teacher's bench. 3. Compare their observation with these two ladles. 4. Class discussion.	• Water vapour in the air condenses on the surface that is cooler than the surrounding and becomes liquid water; but no water condensed on the surface when there is no temperature difference.	• Two identical objects (ladle A and B)	• A ladle at room temperature • Another ladle placed in the ice box

Table 5.11 Pattern of variation used to serve the function of contrast in dealing with condensation

Activity 4 (Pupil demonstration)	Discernment	Not varied	Varied
1. Pupil's own choice of object put in the ice box. 2. Compare the observation with that of the cooled ladle. 3. Class discussion.	● Water vapour in the air condenses on surface other than metal that is cooler than the surrounding and becomes liquid water;	● Objects in the ice box.	● The ladle ● Other objects suggested by pupils.

Table 5.12 Pattern of variation used to serve the function of generalisation in dealing with condensation

After the activities were discussed in details, the team began to consider how to help pupils put their thinking together in the discussion part of the lesson. The four teachers thought that some notes should be provided for pupils to study at the end of this lesson; this was the normal practice. In the beginning, the worksheet was designed in such a way that some statements were included to help the class memorize the facts, such as the following "fill-in-the-blanks" exercise:

Water ____________ to become vapour in the process of ____________.

Vapour ____________ to become water again in the process of __________.

The reasons for doing this were discussed as follows:

TD : *Guiding the pupils to the conclusion is difficult; they may not be able to participate. I think we better provide answers.*

TA : *My class is the weakest among the four. I don't think this can work. And do you think we can have enough time to do so? We have to teach them after they have reported back about their observation, right?*

R : *Why not use their reporting back to arrive at the conclusion?*

TC : *But the worksheet must be so designed that there should be the summary of the lesson for revision. This is very important for the examinations.*

TB : Yes, or else the parents will blame us.

However, after the first cycle of teaching, the teachers suggested modifying the worksheet. This point is discussed below, when conducting the post-lesson conferences.

5.4.2 Stage 2

5.4.2.1 Implementation of the research lesson

The research lesson adopted a scientific inquiry approach that consisted mainly of demonstration experiments, group discussions, and whole class discussions. Each of these teaching strategies was guided by the pattern of variation that had been carefully considered in the planning stage. Tables 5.9 to 5.12 show how the patterns of variation were used in the lesson. As noted, a test tube of 5 ml of water was placed at the back of the classroom away from the window three days before the lesson and pupils observed and reported on their experiment at home with water on a small plate. The following table (5.13) briefly outlines the flow of the research lesson.

Activity 1 (Teacher demonstration)	1. Boil a test tube of 5ml of water, level marked in red before boiling. 2. Compare the level of water after boiling for three minutes with that placed in the classroom for three days. 3. Group discussion and reporting back
Activity 2 (Class discussion)	1. Report the observation of the result with the water put on the plate at home three days ago. 2. Compare the result with the test tube of water put in the classroom three days ago. 3. Class discussion.
Activity 3 (Teacher demonstration)	1. One ladle (A) put in the iced cooling box before the lesson. 2. One ladle (B) placed on the teacher's bench. 3. Compare their observation with these two ladles. 4. Class discussion.

Activity 4 (Pupil demonstration) ***(Note: This activity is added in the 3rd cycle of teaching)***	1. Pupils' own choice of object put in the ice box. 2. Compare the observation with that of the cooled ladle. 3. Class discussion.
Conclusion	Summary on the blackboard done together with the class.
Extended activity	Problem to think as homework (worksheet): "Given a mug, how can you turn that into a magic tool for water vapour in the air to condense on it?"

Table 5.13 Flow of the research lesson

The research lesson was first taught by Teacher C to class 3C and observed by the other members of the team. After administering a post-test identical to the pre-test, the team gathered for a post-lesson conference. Allowing ample time in between the first and the second cycle is important, because, no matter how careful and insightful we are, there will always be something in the lesson that we have to review and modify. The videotapes of the lessons and the post-lesson pupil interview provided the team with the possibility of analysing the lesson in detail. Changes to the lessons were made, especially with the focus on how teachers could further help pupils develop the concepts. These are described in the paragraphs that follow.

5.4.2.2 Assessing the research lesson

5.4.2.2.1 Post lesson pupils' interview

Three pupils from each class were selected, again, on the basis of their perceived academic ability as assessed by the teacher, high, medium and low, for the post-lesson group interviews that were conducted by the principal researcher. In other words, pupil selection was not based on the results of either the pre- or the post-test. The purpose of the interview was to better ascertain how well the pupils had learnt the lesson and what had helped them learn. Another purpose was to allow the pupils opportunities to further elaborate their written answers in the post-test. The interview was video-recorded for the purpose of analysis.

Pupils were asked to explain further what they meant by the expression "it's evaporated". It confirmed our earlier assumption that pupils would think that providing the scientific terms constitutes the perfect answers. One of the pupils, who had only achieved Category E4a in the post-test, when interviewed, was able to explain that: "I mean that the water has evaporated....that means it has changed to vapour". This shows that this pupil's understanding of the concept was actually at Category E4b instead of E4a. Another pupil who said that "the can is cold" (Category C3) in the written response could further explain, "It's the cooler surface and so the hot air can have water on it." Though at the end she was unable to demonstrate a full scientific concept, the teachers were encouraged that the interview provided more complete pictures of their pupils' learning. Given that the categories outlined in the previous tables provide a conservative estimate of pupils' learning, based on the written test, the limitation of using those categories has to be acknowledged. In short, pupils may actually know more than they are able to present in their written answers.

The tables (Tables 5.5 and 5.8) above provide data on pupils' conceptualisation of condensation and evaporation prior to the lesson, providing the teachers with a clearer understanding of the pupils' starting points. A comparison of the pre and post-test data, showing the extent of the learning achieved, are given in Table 5.14 to 5.21 for the four classes.

5.4.2.2.2 Post-lesson conference and post-test analysis of each cycle of teaching

The post-lesson conference held after each cycle was crucial in conducting the Learning Study. It is not common for Hong Kong teachers to openly comment on another teacher's lesson, though peer observation has been practiced in Hong Kong for a few years. Following the pupil interviews, the team sat together to discuss the lesson. Everyone participated eagerly in the discussion. Genuine and constructive comments were made. Critical questions were asked, but it is important to note that the teachers were making criticism and reflections in a *safe* environment. The criticism was geared towards the improvement of the lesson to help pupils learn better, not to undermine the efforts of the respective teacher. In what follows, two examples of teaching episodes (in 3C and 3D) will be considered, as an illustration to show how the patterns of variation were used to help discernment. Teachers' discussion of the teaching episode of 3C is also considered as an example of the kind of discussion that occurred in the lesson conferences, which highlights how key points were identified and incorporated into the study. This is followed by an overview of all four post- lesson conferences, held after each of the four separate teaching cycles.

One key point raised by the teachers during the post-lesson conference following the first lesson cycle concerned the teacher's elicitation technique. They thought that there were many opportunities in the lesson where the teacher might have missed helping pupils develop their concept. Only if teachers are sensitized to these opportunities, can pupils' learning be improved. The team made use of the following teaching episode after the first cycle in discussing this point.

> *Teaching episode of 3C:*
>
> *TC asked one of the pupils, Anna to come out and mark the level of water on a test tube filled with 5-ml of water. TC then boiled that test tube of water for a few minutes. She then asked the class, "What will happen to the amount of water in the test tube after boiling?" Another pupil, Daisy, was called upon to mark the new level of water on the same test tube. As Daisy did so she whispered to herself satisfactorily, "I knew it!" TC quickly followed up and asked the class: "what did Daisy know?" The whole class shouted out, "The (amount of) water becomes less!" TC asked, "Can you tell me why?" "Because water was boiling," said the class.*
>
> *TC then directed the pupils' attention to the test-tube that was put in the corner three days before. "Michael, I want you to look at the test tube you had put in the corner three days ago." Michael reported to the class after he had checked the water level, "The water becomes less."*
>
> *TC posed the question to the whole class, "As you see, water in the two test-tubes becomes less under different conditions, why?" The class then started to discuss in groups on the observed phenomenon and prepared to report back.*

The team thought that if Teacher C followed with a question to the whole class asking why boiling could make the water less, before making the comparison, the class would be guided to think about the fate of the water. This was a critical point that the team reiterated many times in the meetings.

This teaching episode also illustrates how evaporation at boiling point and at room temperature were presented to the class, by making use of the pattern of variation to serve the function of fusion. Two related critical features were discerned, (CF1) the loss of water indicates the occurrence of evaporation and (CF2) water evaporation may take place at different temperatures. Note that the discussion deliberately ignored the *speed* of evaporation, focusing instead on why the water disappeared. It was decided that the destiny of the water, as a result of the change of state, would provide the main focus. This is important, because pupils must first realise that the water's disappearance, as witnessed in their daily lives, was due to evaporation, before moving to the later part of the lesson about the invisibility of gaseous water in the air. This principle guided the design of the remaining research lessons.

Below is another teaching episode in the third cycle of teaching by Teacher A, transcribed to show how the pattern of variation was used in the lesson.

> *Teaching episode of 3A:*
>
> *TA took out the metallic ladle from the cooling box and after a while asked the class, "What can you see on the ladle?" The class, "it is not clear." TA, "can someone come out?" Hands raised and TA called upon Tony to come out. "Come closer, what can you see on the ladle?" Tony said, "some small water drops." TA asked Tony to touch it and tell the class. Tony said, "Yes, it's wet." TA then asked the class, "Where has the water come from?" Some shouted out, "from the ice-box." TA asked Vivian to come out and wipe the ladle dry, and asked Vivian to observe the ladle closely, "What can you see?" Vivian, "Some mist appears again." TA, "so can it come from the box when you have wiped it dry already?" Vivian, "No." And she went back to her seat.*
>
> *TA continued by asking a few more pupils to express their views on the source of this water, and encouraged them to consider if there was water vapour in the surrounding air by referring back to the experiment on evaporation. At that point, the head teacher pushed open the door of the classroom and came into the room. A boy shouted out loudly, "some vapour must have escaped…."*

This teaching episode of 3A, when the boy experienced a 'eureka' moment, was followed by pupils making a comparison with another ladle B put on the teacher's bench to see if there was any water on it. The teachers appreciated that this pattern of variation served the function of contrast, in that one ladle was cooled while the other was not. The discernment occurs in regard to that which has varied: the temperature. Noticing this variation, it is believed, helps pupils make the connection between the formation of water and the cooler surface. When the class were invited to make suggestions on the items to be put in the cooler to test for this effect, objects like pencil cases, mirrors and rulers were put forward. In one of the classes, a pupil even asked for the head teacher's pair of spectacles! We will now consider each of the post-lesson conferences in more detail.

5.4.2.2.2.1 The first cycle of the research lesson (3C)

In the post-lesson conference, Teacher C began to express her views about her lesson.

TC	:	*I have never seen my class so keen in putting up hands for the questions.*
TD	:	*Yes, they were so excited. May be we have planned the lesson in such an organized way.*
R	:	*How do you find the worksheet? Do you all think that it can help the pupils to work towards the conclusion?*
TA	:	*I think the worksheet is too clumsy, too many blanks for the pupils to complete. I would rather cut away the last part on the factual statements.*
TC	:	*I agree, it should be a record sheet but not an exercise.*
TB	:	*At first, I thought that it should be so, with so much input from us. You really don't know how it works until you use it...*
TA	:	*The worksheet should be simpler. I think pupils should learn the concept, not rote-learn the factual statement. Can we re-write this part?*
TD	:	*Too much time has been used to check their answers on the worksheet.*
TB	:	*We should allow them time to ask us questions.*
TC	:	*You can try in your lesson.*

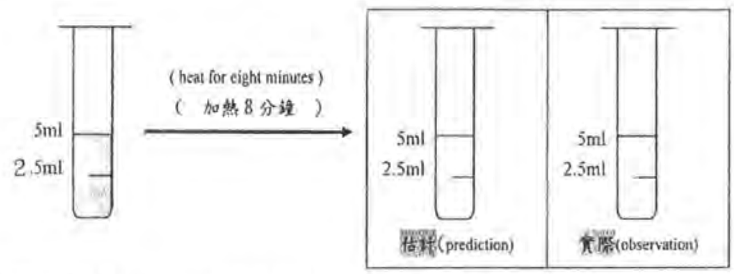
Box 5.2 Original worksheets

《水》單元之"水的蒸發與凝結" 工作紙

(Worksheet on the evaporation and condensation of water)

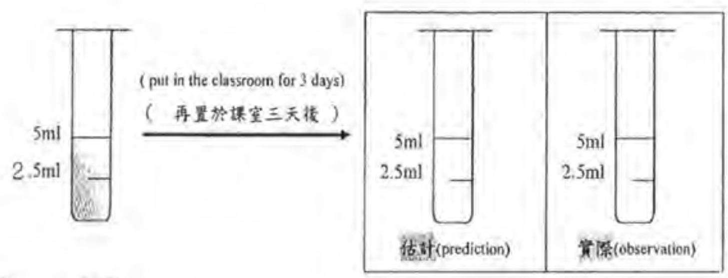
活動 1 將 5ml 水加熱 8 分鐘，估計水的刻度有甚麼變化?

(Activity 1 Heat 5 ml of water for about 8 min., is there any change to the volume?)



活動 2 三天前，我們將 5ml 水注入試管，再置於課室，試估計現在水的刻度有甚麼變化?

(Activity 2 What happens to the 5 ml of water in the test tube when placed in the classroom three days ago?)



我們的發現 (Our discovery) :

	活動一 Activity 1	活動二 Activity 2
試管內的水量 (Water in the test tube)	(多了 /少了/不變) (becomes more/becomes less/no change)	(多了 /少了/不變) (becomes more/becomes less/no change)
水蒸發的溫度 (Temperature of water when evaporates)		
蒸發的速度 (Rate of evaporation)	(較快 / 較慢) (faster/ slower)	(較快 / 較慢) (faster/ slower)

結論 Conclusion :

1. 水 (   ) 要加熱至沸點才能蒸發。

(1. Water (   ) can evaporate at its boiling point.)

2. 水蒸發變成(   )。

(2. Water evaporates and changes to (   ).)

3. 水遇熱變成 (   )，這過程叫做(   )。

(3. Water changes to (   ) when meet something hot, this process is called (   ).)

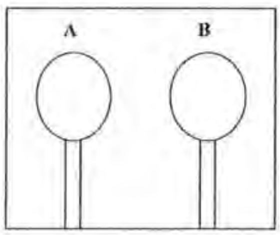
Box 5.3 Original worksheets (continued)

活動 3

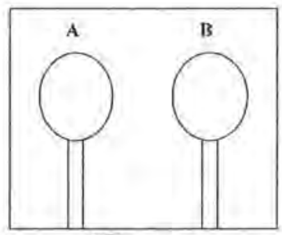
將兩隻金屬湯匙，一隻放於冰箱 (A)，一隻置於課室(B)；
將兩隻湯匙取出，用乾布抹乾，等待三十秒，估計它們的變化。

(Activity 3 There are two ladles, one is put in the cooler (A) and the other put in the classroom (B). Take the two ladles out and wiped dry. Wait for 30 seconds and predict the changes.)

*在方格內畫出可能的變化 (Draw the possible changes on the ladles)



估計 (prediction)



實際 (observation)

哪隻湯匙表面有小水點?

(Which ladle has water on it?)

(A / B / A 和 B 都有 / A 和 B 都沒有)

(A / B / both A and B / neither A nor B)

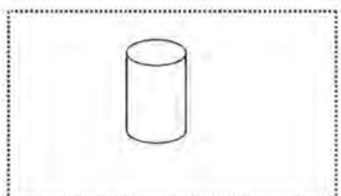
結論 (Conclusion):

- 水是從 (空氣/湯匙)裡來的。
- (Water comes from the air / the ladle.)
- 因為湯匙(A / B) 的表面較課室的溫度(高 / 低)，所以 (空氣 / 湯匙) 中的水能在(湯匙 A / 湯匙 B)的表面 (蒸發/ 凝結)。
- (Because the temperature of ladle A / ladle B is cooler than that of the classroom, therefore water in the air/ the ladle evaporates / condenses .)

挑戰站 (The challenge)

有什麼方法能令課室內空氣的水於玻璃杯上現形?把方法以繪圖形或文字簡單表示出來。*嘗試利用其他方法*

(What can you do to make the vapour in the air to re-appear on the glass? Draw or explain your methods in simple words.)



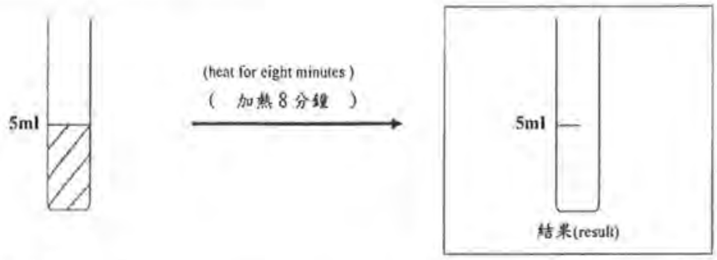
Box 5.4 Revised worksheets

《水》單元之"水的蒸發與凝結" 工作紙

(Worksheet on the evaporation and condensation of water)

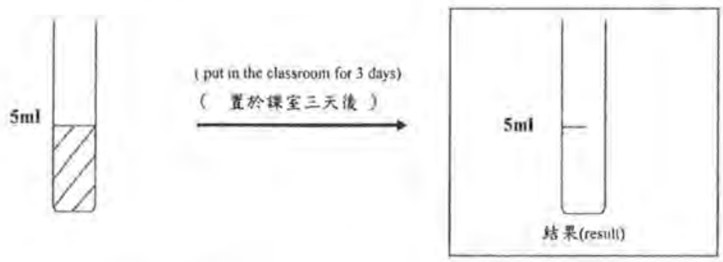
活動一 將 5ml 水加熱 8 分鐘，水的刻度有甚麼變化?

(Activity 1 Heat 5 ml of water for about 8 min., is there any change to the volume?)



活動二 三天前，我們將 5ml 水注入試管，再置於課室，現在水的刻度有甚麼變化?

(Activity 2 What happens to the 5 ml of water in the test tube when placed in the classroom three days ago?)



我們的發現 (Our discovery)：

	活動一 Activity 1	活動二 Activity 2
試管內的水量 (Water in the test tube)	(多了 /少了/不變) (becomes more/becomes less/no change)	(多了 /少了/不變) (becomes more/becomes less/no change)
水蒸發的溫度 (Temperature of water when evaporates)		
蒸發的速度 (Rate of the evaporation)	(較快 / 較慢) (faster/slower)	(較快 / 較慢) (faster/slower)
蒸發了的水到了哪裏? (Where has the evaporated water gone?)		

為什麼 ? (Why?)

1. 液態水在( ) ℃ 以上至( ) ℃ 以下會蒸發。

(1. Liquid water above ( ) ℃ and below ( ) ℃ will evaporate.)

2. 水蒸發的速度是受( ) 高低影響。

(2. The rate of evaporation is affected by ( ).)

3. 試管內的水是由( )態轉變成( ) 態，分佈於空氣中，這過程叫做 ( )。

(3. The water in the test tubes changes from ( ) state to ( ) state and goes to air. This process is called ( ).)

Box 5.5 Revised worksheets (continued)

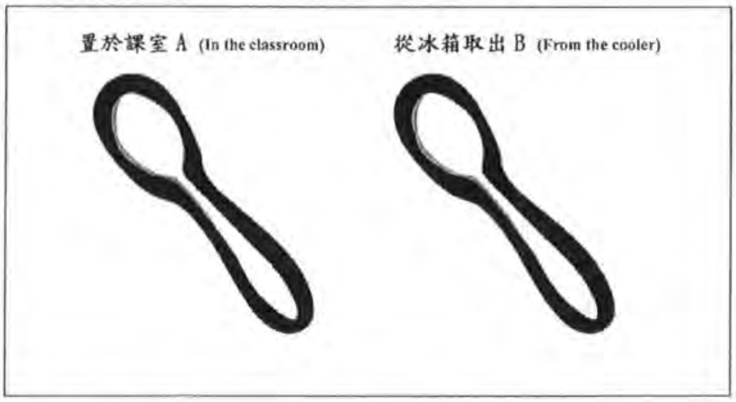
活動三

有兩隻金屬湯匙，一隻置於課室 A，一隻從冰箱取出 B；

等待三十秒後，它們分別有甚麼變化?

Activity 3

(Put a metallic ladle in the classroom and take another metallic ladle from the cooler. Observe the two ladles after 30 seconds. Draw what you've observed.)



我們發現 (We discover):

____

為甚麼 (Why)?

____

____

____

Box 5.6 Revised worksheets (continued)

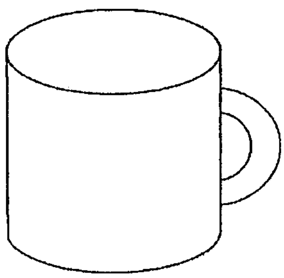
挑戰站 (The challenge):

有甚麼方法能令空氣中的水汽於杯上現形?

(What can you do to make the vapour in the air to re-appear on the mug?)

把方法以繪圖形或文字簡單表示出來。

(Draw or explain your method in simple words.)



The original worksheets (Boxes 5.2 and 5.3) that were prepared by the teachers and used in the first cycle provide an interesting window onto the teachers' conceptualisation of the learning of this topic. The researcher restricted herself from dominating on the design of the worksheet before the research lesson. Teachers needed to realise the strengths and the weaknesses of the worksheet after using it once and make changes accordingly. The teachers wanted to focus on making the language and the instructions clearer, so that pupils could follow more easily. This attention to detail represented a major change in the way teachers considered bringing about pupils' learning. However, after using the worksheet once, the teachers suggested three modifications:

1. Diagrams provided about the test tubes were considered confusing, because lines on the tubes suggested a water level, so pupils didn't draw it on as they thought the result of the water level had already been provided. Also the line on the top of the test tube suggested there was a cover on the tube, which was not correct and was confusing. The diagrams were re-drawn.

2. Filling in the blanks after activity 1 was meant to be an exercise and to provide a summary for the pupils, which the teachers thought to be the most important part of the lesson as it provided a text for pupils to go home and study. After the first cycle, one of the teachers asked about the purpose of putting this exercise in. The team discussed the use of the worksheet and how this part should be the conclusion drawn after the activity. The worksheet was reconsidered and reframed so that it served to develop pupils' concepts rather than provide a recollection of the facts about evaporation.

3. The "Challenge" activity at the end of the worksheet was meant to be an activity conducted at home. The initial design did not allow space for pupils to freely express their ideas and thinking, because teachers underestimated pupils' ability in completing this activity. (They expected most pupils would not be able to do it.) However, at the end of the first cycle, a number of pupils were keen to know where they should draw or write down their thinking. This provided insights to teachers about how pupils might be motivated to learn. In order to make the "Challenge"

activity more interesting, it was put on a new page so that pupils could draw or write down their ideas more freely.

The worksheets were then revised as shown in Boxes 5.4 to 5.6. The issue on the design of the worksheet was only one among the many agenda items of the conference meeting. The team made suggestions and recommendations based on evidence gathered through lesson observation, pupils' interviews and the post-test results. The data analysis is a crucial process for the teachers to understand whether and what their pupils' have learned in the lesson.

Data analysis on the post-test was also performed by the team, using the same categories as those for the pre-test. Going through pupils' responses with the teachers allows them to learn more about how well their pupils had learnt, as we have mentioned earlier. A comparison of pupils' responses (class 3C) to questions on evaporation and condensation in the pre- and post-test is given in the tables 5.14 and 5.15.

Categories / Frequencies	E1		E2		E3		E4			
							E4a		E4b	
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
Pre-test	14	5	3	2	11	18	1	4	0	0
Post-test	1	2	0	0	5	5	20	19	3	3

Table 5.14 Frequency of 3C pupils' responses to questions on evaporation (N=29)

Categories / Frequencies	C1		C2		C3		C4			
							C4a		C4b	
	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4
Pre-test	11	8	3	6	14	13	1	2	0	0
Post-test	3	1	2	3	7	10	8	6	9	9

Table 5.15 Frequency of 3C pupils' responses to questions on condensation (N=29)

The data shows that there are still a number of pupils with no concept of water changing to a vapour and its reverse in evaporation and condensation (Categories E1, E2; C1, C2). The teachers were surprised to find that pupils' responses in Category E3 and C3 in the post-test have been enriched with more detailed explanation. The team was interested to find a response to question 3 in the post-test as follow:

> *Because one coca-cola can has not been put in the refrigerator, so it's warm. While another one has put in the refrigerator, the cold air and warm air meets and there are water drops. (3C: 18)*

The teachers exclaimed that for the first time they were able to know what's in the pupils' minds. They said that they began to realise there was not only "right" or "wrong" answers, but incomplete answers which could help them to track the pupils' level of understanding. We spent some time in looking at this pupil's response and the related discussion was as follows:

> *TA : It's strange that the pupil mentioned another can, not mentioned in the question.*
>
> *TC : It must be the experiment...there are two ladles; one is not in the cooling box.*
>
> *R : Can you evaluate her learning then, has she learned?*
>
> *TD : She must have learned something...She has learned to apply it in another situation.*
>
> *TC : I think so. The contrasting effect on the two ladles leads her to start solving a new problem with something she has learned.*

The team was able to learn from the data and tried to tease out the obstacles in pupils' learning. Teachers carefully analysed the data and, as a result, the following findings were listed:

1. The correlation of pupils' level of understanding between the two questions on evaporation and the other two questions on condensation is high in the post-test. This suggests that most pupils were able to make generalisations across similar situations and could identify cases related to evaporation and condensation. For example, when examining the results of Q1 and Q2 on evaporation, the numbers of pupils placed in Category E4 is virtually the same for both questions, which suggests (but does not prove) that even though the background phenomena for each question is different, pupils were able to demonstrate similar levels of understanding about evaporation.

2. 20 pupils in question1 and 19 pupils in question 2 suggested that 'the sun has evaporated the water' or expressions like "it has evaporated" or "evaporation" (Category E4a). In both questions, only 3 pupils mentioned that the water has changed to vapour and continued to be present in the air (Category E4b). However, pupils' responses to questions on condensation were very different. Pupils tended to give more detailed explanation for condensation questions than for evaporation. Not many pupils put down 'because vapour condenses to water' in their responses. Rather, response like 'because the steam meets something cold and changes to water' was more prevalent. Since this group of pupils could not specifically point out where the vapour came from and what the cold objects were in the process of condensation, the team agreed to classify this group of pupils at C4a. It was very encouraging to find 9 pupils in this class could give a very complete explanation for the condensation phenomenon (Category C4b). Similar views like the one following were given:

> *"Because the can is cold, vapour in the air meets the cold can and changes to water." (3C: 24)*
>
> *"Because the lid is cooler, the steam meets the cold lid and changes to vapour." (3C: 24)*

The teachers were amazed to find this pupil could even differentiate the source of vapour in the two cases. In order to find out why pupils could explain the phenomenon of condensation better, the team watched the videotape of this lesson. We found that Teacher C emphasised the statement 'the water has evaporated' many times during the discussion of Experiment 1. Whereas in discussing about the water formed on the cold ladle in Experiment 3, a number of pupils were invited to pose their explanations. The "cold" ladle was emphasized with comparing it with the other ladle. The terms "condensed" or "condensation" was not emphasized in the discussion. This finding vividly illustrates the relationship between teacher's enactment and pupils' learning.

3. For Categories E3 and C3, expressions like "the sun sucks up the water", "the fridge is cold", "because the hot steam" or "hot met cold" were not as prevalent in

the post-test as in the pre-test. Instead, expressions like "the can is cold" or "the lid is cold, therefore there are water drops" are more common. The expression "because the temperature is lower" is found in the post-test but not in the pre-test. The teachers suggested that pupils in this category had grasped one of the critical features that something cooler must be present for condensation to take place, although, the notion that the disappearing of water to the air and the continuing presence of water vapour in the air were absent. Teacher B agreed that this critical feature should be carefully elaborated in his lesson, the second cycle.

4. A number of pupils had progressed in their understanding of the concepts on evaporation and condensation. The following is the result of a pupil who has arrived at Category E4a after the lesson, whereas he was in E1 in the pre-test on evaporation. (3C:17)

Question 1
Pre-test (at Category E1)

The puddle of water will disappear after school. It is because the puddle will dry up completely after some time.

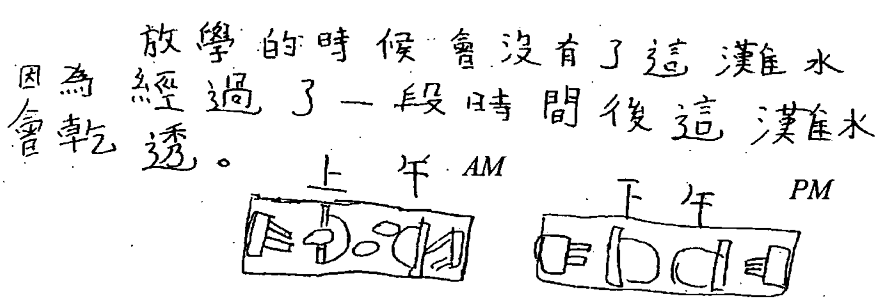


Figure 5.1 Response of pupil 17 of 3C to Question 1 of the pre-test

Post-test (at Category E4a)

It is because the puddle of water evaporates into water vapour.

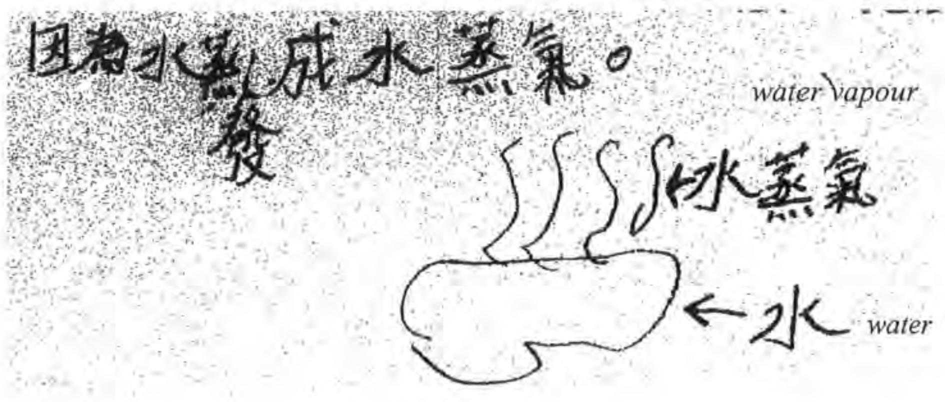


Figure 5.2 Response of pupil 17 of 3C to Question 1 of the post-test

5. The following was another sample of a pupil's pre- and post-test (3C:23) result in question 3 about the concept of condensation. The pupil could only repeat the phenomenon of having water on the lid without giving any explanation, whereas in the post-test, the pupil has tried to explain, though in simple words, the water appeared because there is a different in temperature between the hot water in the mug and the lid.

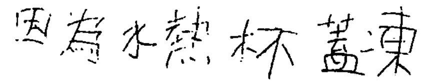
Question 3

Pre-test (at Category C1)

There is some water on the lid.

Figure 5.3 Response of pupil 23 of 3C to Question 3 of the pre-test

Post-test (at Category C3)



Because the water is hot and the lid is cold..

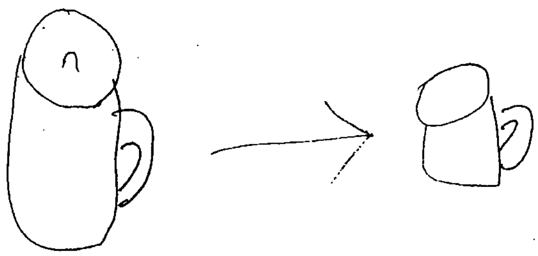


Figure 5.4 Response of pupil 23 of 3C to Question 3 of the post-test

This pupil did not use the term "condensation", but one can see from the answer given, the chain of thought is going in the right direction. The pupil is combining the crucial point of hot meets cold, which is the beginning of discernment about the nature of condensation.

Overall, teachers analysed the first cycle of the research lesson and identified both its strengths and weaknesses. What they learned from it went towards improving the subsequent cycles, where the improved versions of the lesson were taught to the remaining classes.

5.4.2.2.2.2 The second cycle of the research lesson (3B)

The team started the meeting by discussing the revised worksheet and agreed that the changes made helped pupils focus on the discussion instead of rote-learning a few facts after the experiments. The post-test result was analysed by the team. However, they were surprised to find that only about half of the pupils were able to give responses in Category E4. Not even one pupil was able to mention the term 'condensation', nor explain in his or her own words the phenomenon of condensation. The results of the pre-and post-tests are provided in Tables 5.16 and 5.17.

Frequencies \ Categories	E1		E2		E3		E4			
							E4a		E4b	
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
Pre-test	10	8	0	0	10	12	0	0	0	0
Post-test	5	3	0	0	9	7	6	10	0	0

Table 5.16 Frequency of 3B pupils' responses to questions on evaporation (N=20)

Frequencies \ Categories	C1		C2		C3		C4			
							C4a		C4b	
	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4
Pre-test	17	18	1	0	2	2	0	0	0	0
Post-test	6	5	4	6	10	9	0	0	0	0

Table 5.17 Frequency of 3B pupils' responses to questions on condensation (N=20)

In summary, the team observed the followings:

1. This class is weaker than 3C, the first cycle, with no pupil arriving at E4b and C4b.
2. The learning of the concept on evaporation is better than condensation, but just on the reproduction of the term "evaporation" without providing an explanation of where the water has gone.
3. With regard to the concept of condensation, pupils are found to provide answers like "that the can or the lid is cold", which suggests that the critical features of a cooler surface is recognised, but yet pupils could not state the source of the water.

Based on the above observation, the team suggested watching the videotape of the lesson again. This was useful in helping the team recapture the lesson to analyse it with respect to the enactment of the teachers and how that might affect pupils' learning. The following issues were discussed, as the lesson was analysed: -

1. The teacher's view of science learning, which is predominantly teacher-centred and tends to produce passive pupil learning. Repetition of the facts in the lesson was obvious and took up most of the time in the lesson.

2. The teacher tends to ask many didactic and closed questions like "the water in the air is called ____________" or "so water changes to vapour is called

________________". Pupils were not encouraged to express themselves freely in their answers. Rather they were encouraged to guess the expected answers. So the lesson progressed in such a way that most pupils shouted out irrelevant answers in the guessing process.

The team realised that after all the discussion and the modification to the first cycle lesson plan, the second cycle produced poorer results, which was somewhat surprising as the teacher concerned was the only qualified science teacher in the team of four. Perhaps, however, that is not simply a problem; it may also be part of the solution. The teacher may well have harboured the idea that his teaching is already very good, and not in need of development, such feelings are not uncommon in well-experienced and qualified teachers in Hong Kong, as elsewhere. On top of that, however, he is a rather traditional and conservative teacher, believing in the merits of rote learning. That may have its merits, but in this study the aim was to develop pupil' conceptual learning, and that is not easily done by rote. It was noticeable that he was silent when watching the videotape of his own lesson. He already knew that the post-test showed that the responses provided by his class were only up to Category C3 for condensation, indicating there was no deep learning of this concept. This he found embarrassing, but he seemed unable to correlate the lack of pupil learning with his teaching. In terms of Learning Study theory this is explained as a difference between the intended object of learning and the lived object of learning. What the pupils experienced in terms of the enactment of the teacher was not up to the level required to understand the change of state in the process of condensation.

Below is a sample of one pupil's (3B:17) answers to question 2, about the drying of the wet laundry and question 4, on the appearing of water drops on the cold can. The pupil's work shows that her learning of the concept on evaporation is better than that of condensation. When observing the lesson it was not difficult to explain the reason. In the activity of the cold ladle taken out from the cooler, Teacher B was anxious to show the water drops on the ladle. He walked around the class, and kept asking the pupils if they could see the water drops on it. So the focus was on the appearance of the water drops instead of on the reasons why. The pupils were not involved in expressing their thinking. Instead, the teacher kept repeating that because this ladle was cold there were water drops, whereas the other ladle not exposed to the cold had no water drops on it. The term "condensation" was also not introduced in discussing this issue. In reflecting on this incident, the team began to realise why not one pupil in this class attained the C4a level of understanding (refer to Table 5.17).

Question 2

Pre-test (at Category E2)

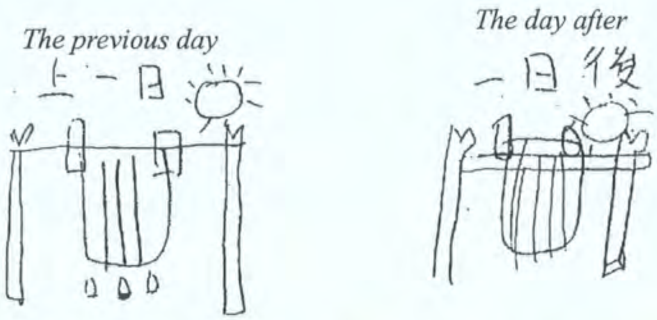


Figure 5.5 Response of pupil 17 of 3B to Question 2 of the pre-test

Post-test (at Category E4a)

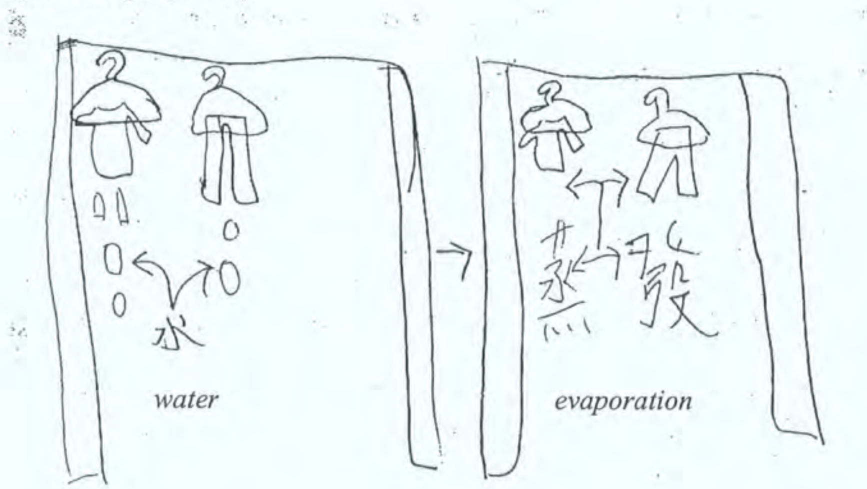


Figure 5.6 Response of pupil 17 of 3B to Question 2 of the post-test

Question 4

Pre-test (at Category C1)

It freezes and is hard

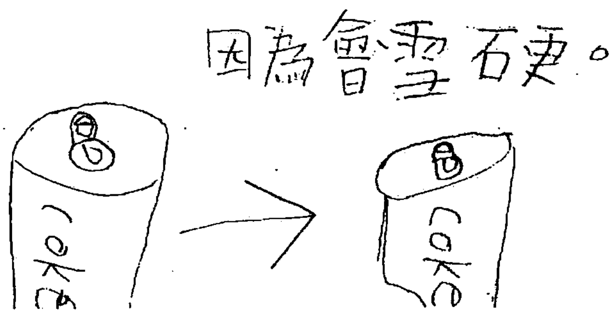


Figure 5.7 Response of pupil 17 of 3B to Question 4 of the pre-test

Post-test (at Category C3)

Because the freezer is cold, so there should be water drops

water drops

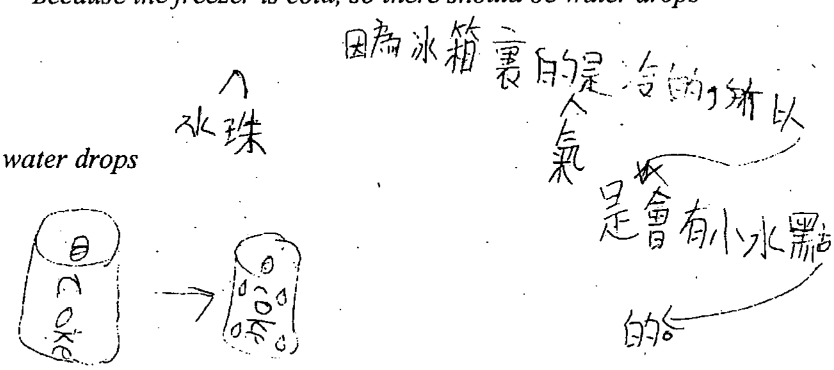


Figure 5.8 Response of pupil 17 of 3B to Question 4 of the post-test

By carefully analysing the lesson, the team began to realise the close relationship between teacher's enactment of the lesson and pupils' learning. Things in this lesson would have been much different if the teacher had moved from getting his pupils to observe the phenomena, to asking the question "why?". Learning Study provides a venue for this kind of professional dialogue and analysis to take place. This requires reflections of the teachers, aided by the input of expertise from the higher education sector. It is most unlikely that teachers, left to their own devices, would have the time or awareness to notice the subtleties involved in this kind of teaching and learning situation. It is often small things that make a big difference in pupil learning. Things in this lesson would have been much different if the teacher had moved from getting his pupils to observe the phenomenon, to asking the question "why?".

5.4.2.2.2.3 The third cycle of the research lesson (3D)

Categories / Frequencies	E1		E2		E3		E4			
							E4a		E4b	
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
Pre-test	4	0	0	0	24	31	4	1	0	0
Post-test	0	1	0	0	10	14	20	16	2	1

Table 5.18 Frequency of 3D pupils' responses to questions on evaporation (N=32)

Categories / Frequencies	C1		C2		C3		C4			
							C4a		C4b	
	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4
Pre-test	11	6	7	6	14	20	0	0	0	0
Post-test	3	7	6	4	16	12	1	3	6	6

Table 5.19 Frequency of 3D pupils' responses to questions on condensation (N=32)

Teacher D, teacher of the third teaching cycle, was the panel head of the subject. She is a very humble teacher, and freely admitted her weakness in the subject. Yet she was keen to improve her teaching and enhance her pupils' learning. This can be seen, for example, in the improvement of her questioning technique – such as "What do you find on the cool ladle, after Mabel has wiped it?" Though not part of the original lesson plan, she also encouraged the pupils to make their suggestions about what other objects could be put in the cooler to show condensation. Originally we had only planned to put the ladle into the cooler, but as pupils began to see the generalisation that other objects might react in a similar way, the opportunity opened up to elicit their further suggestions, which they provided with enthusiasm. One suggestion was to put in a piece of mirror into the cooler and another to put in the school principal's pair of spectacles.

In this third cycle, the learning of the concept on condensation showed some improvement, with condensation on the cold can being better explained than the case with the cold lid. Teachers agreed that part of the reason for this was that the situation is less clear-cut. For this question, pupils have to realise that there is a difference in temperature between the cup and the lid, whereas, in regard to the can, it is very obvious that the can is cooler than the surrounding air. However, we found that some pupils (6 out of 32) were able to provide a good explanation for both condensation cases. The sample work provided below shows that this pupil was able to explain the two condensation phenomena. As with the concept of evaporation, from the data given in the tables above, pupils on the whole could only tell that water evaporated, without further explaining where the water had gone. By going over the video-tape of the lesson, the team realised that the critical feature, that of the water existed but in a gaseous form, was not made explicit during the discussion of the evaporation phenomena. The teachers immediately could relate this information about what the pupils were actually learning to their own teaching in the lesson. Throughout the post-lesson conference, the team of teachers formed the habit of critically explaining their pupils' learning in relation to their own actions in class. Teachers could more easily tease out the factors that affect their pupils' learning. In this case, Teacher A, when reflecting on her forthcoming lesson, became aware that she would need to ask the class about the destination of the water vapour during the activity. The teachers as a group hoped that the last cycle would show improvement in this critical aspect.

A sample from the third cycle of a pupil's (3D: 9) answers to the two questions on condensation. He started at Category C3 and attained C4b after the lesson in two different situations.

Question 3

Pre-test (at Category C3)

Water vapour, because the refrigerator is cold.

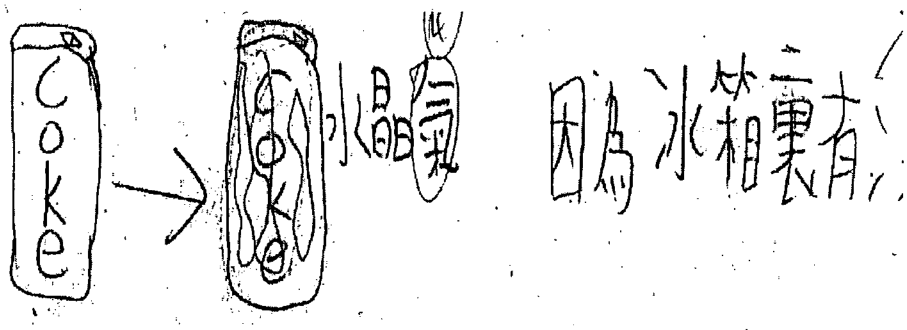


Figure 5.9 Response of pupil 9 of 3D to Question 3 of the pre-test

Post-test (at Category C4b)

The can is cooler than air, so condenses to form water.

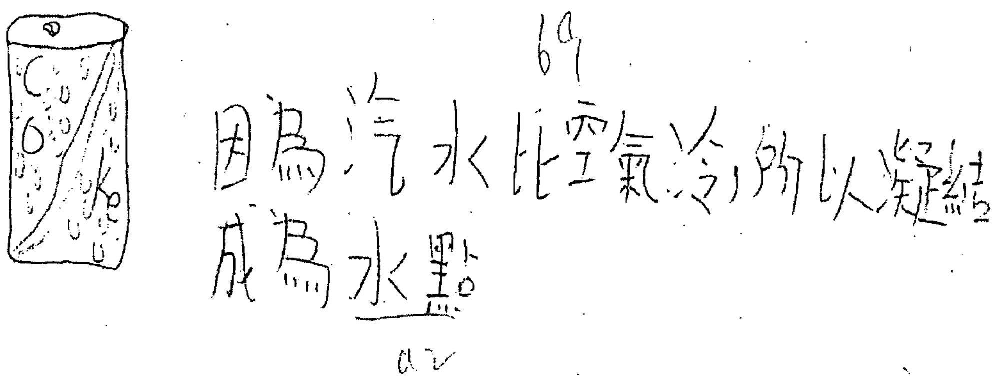


Figure 5.10 Response of pupil 9 of 3D to Question 3 of the post-test

Question 4

Pre-test (at Category C3)

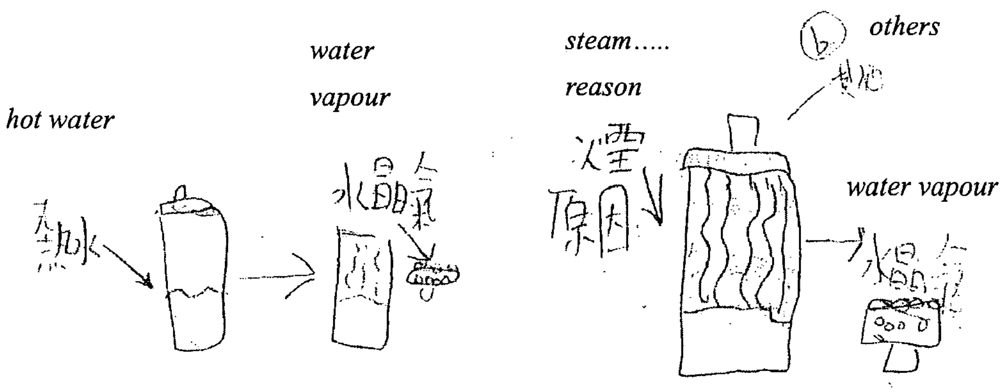


Figure 5.11 Response of pupil 9 of 3D to Question 4 of the pre-test

Post-test (at Category C4b)

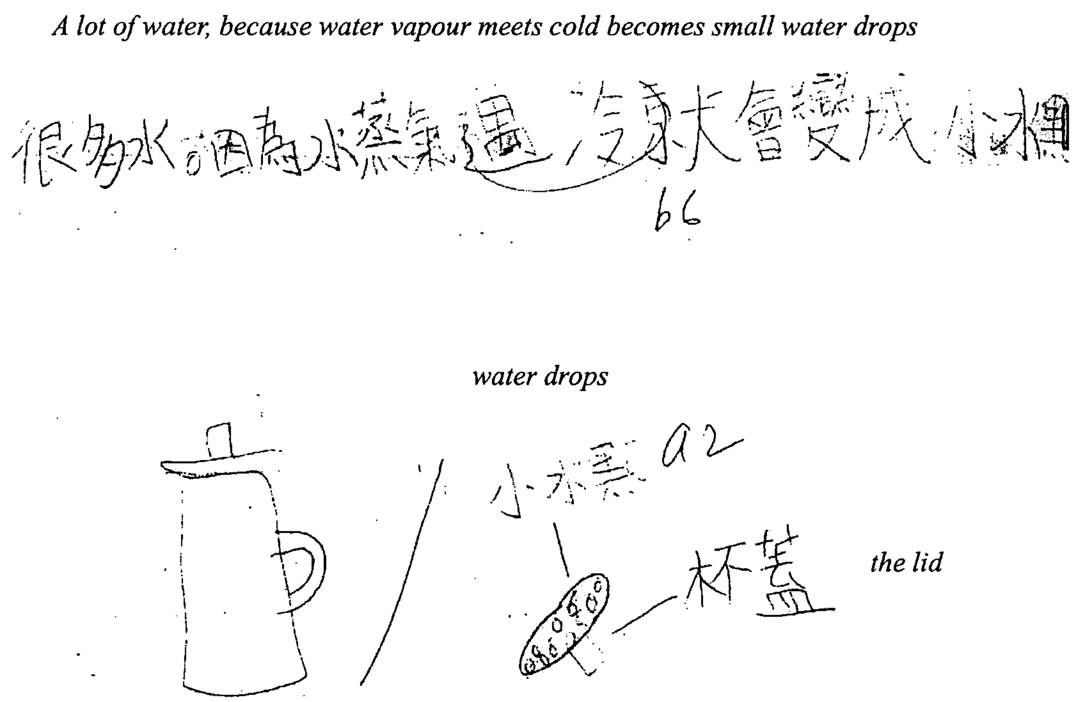


Figure 5.12 Response of pupil 9 of 3D to Question 4 of the post-test

This pupil was able to explain the two phenomena related to the condensation of water vapour to water, by making use of the important factor that there must be something cooler if the water vapour is to reappear. We presume that this pupil should know that there must be water vapour to start with condensation. The concept of phase change is evident in this pupil. The discernment of the critical feature(s) definitely can be a great help for pupils when applying the phenomena to similar situations in their daily lives.

5.4.2.2.2.4 The fourth cycle of the research lesson (3A)

Categories / Frequencies	E1		E2		E3		E4			
							E4a		E4b	
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
Pre-test	15	4	0	2	12	21	0	1	0	0
Post-test	9	5	0	1	8	15	7	5	3	1

Table 5.20 Frequency of 3A pupils' responses to questions on evaporation (N=27)

Categories / Frequencies	C1		C2		C3		C4			
							C4a		C4b	
	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4	Q3	Q4
Pre-test	15	16	4	4	8	7	0	0	0	0
Post-test	10	10	1	1	11	6	1	6	4	4

Table 5.21 Frequency of 3A pupils' responses to questions on condensation (N=27)

Teacher A, teacher of the last teaching cycle, explained that the verbal ability of this class is limited, and their attention span is short. They were not keen to participate in the lesson. However, observation showed that this class concentrated and tried their best to answer challenging questions such as – "I have put the test tube in the classroom for three days, can you guess if the water has reduced?" Many hands rose up and when one pupil was called upon to answer the question, he not only said yes, but also tried to explain his view, "I think the water is less because of the sun." With the teacher deliberately trying to improve her questioning techniques, pupils were able to participate actively in the thinking process. There was one very interesting example of this, noted earlier. The teacher had reached the part of the lesson where the idea that water has evaporated into the air was introduced, when the school principal pushed open the classroom door to enter the room. One boy immediately exclaimed that some of the water vapour had now escaped. He had certainly appreciated the abstract idea that the water vapour was present in the room, though invisible, and that if air left the room then the water vapour must have gone as well. Though the result of the post-test showed not many pupils could arrive at Category 4b for both concepts, Teacher A was very happy to see the class's effort, trying to supplement their answers with drawings. Also she changed her view about pupils' writing ability, as the class had made an effort in answering the questions. Below is the pre- and post-test work of one pupil (3A:9). See how he made use of his drawing and words to express his views.

Question 1

Pre-test (at Category E3)

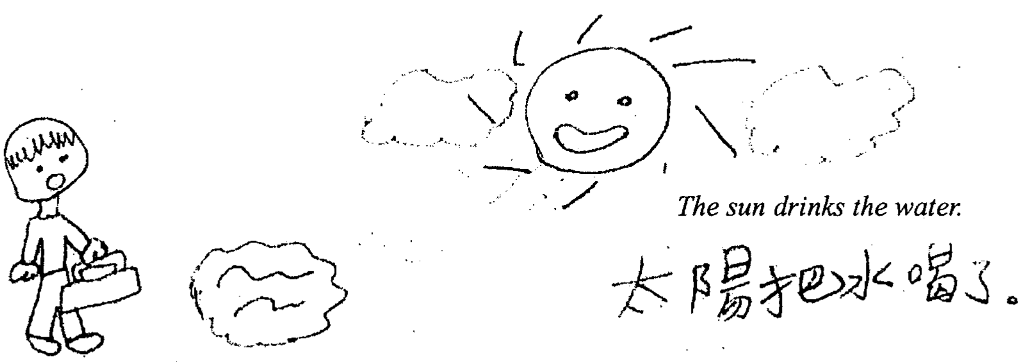


Figure 5.13 Response of pupil 9 of 3A to Question 1 of the pre-test

Post-test (at Category E4b)

It's dry, because the water changed to vapour and flew in the air.

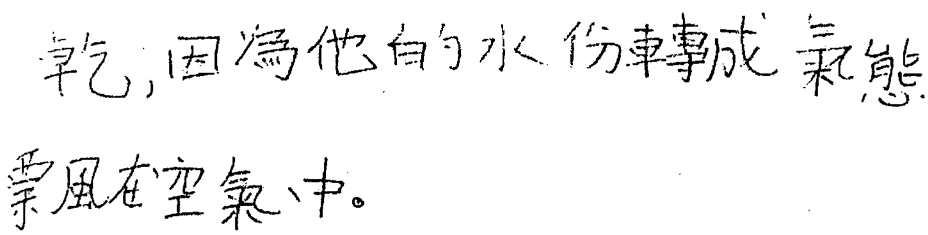
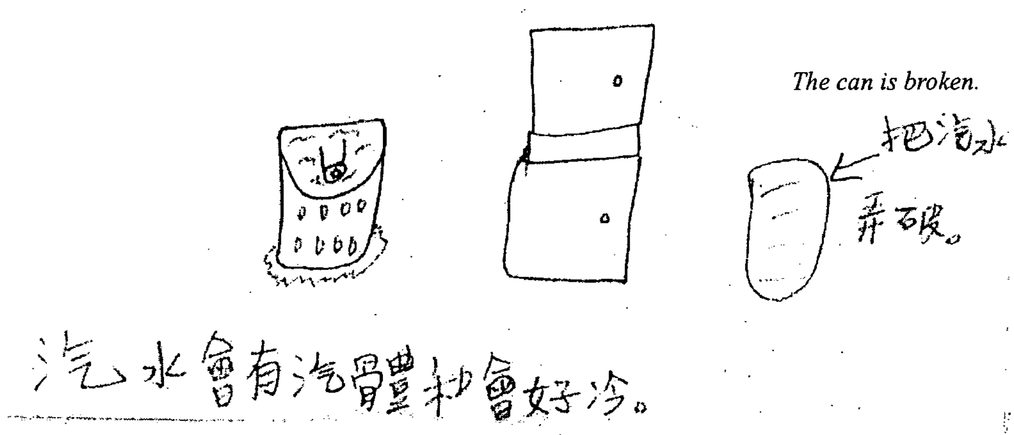


Figure 5.14 Response of pupil 9 of 3A to Question 1 of the post-test

Question 3

Pre-test (at Category C3)



There is gas in the coca-cola and is cold.

Figure 5.15 Response of pupil 9 of 3A to Question 4 of the pre-test

Post-test (at Category C4b)

We discover that there were some water drops on the can of coca-cola. Because the can was cold and when it was taken out, it became hot. Hot and cold and so condensed to water drops.

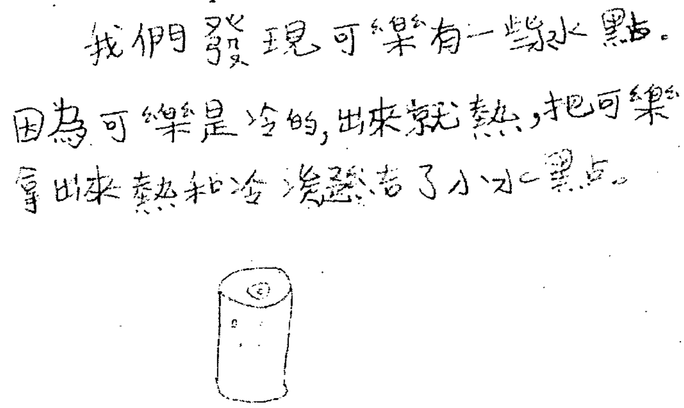


Figure 5.16 Response of pupil 9 of 3A to Question 4 of the post-test

This pupil was able to use expressions to answer the questions on evaporation and condensation, without using much drawing, which he made use to aid his answers in the pre-test. Though there were not too many pupils who were able to do this, it is encouraging to find that some could. This observation has also provided evidence to the teachers that they were able to bring about learning in the pupils, if the lesson was carefully planned.

Nevertheless, as in previous lessons, the learning of the concept of evaporation was somewhat restricted to giving of the scientific term, rather than clearly saying that the water vapour has gone into the surrounding air. In regard to condensation, one pupil in the pre-test wrote, "The vapour from the hot water rises up and meets the lid, and so there is water" (Category C2) to question 3, without mentioning that the lid is cooler. In the post test she added that "the lid is cold and so the water vapour from the hot water changes to water again" (Category C4b). This clearly illustrates that the pupil has grasped the critical feature that relatively cooler object is needed for condensation of water from air to take place.

The fact that not many pupils were able to achieve Category 4b, for both concepts, raises a crucial point that is not sufficiently attended to within the Learning Study process. Despite all the intensive discussion and the enhanced awareness of the teachers on the critical features needing to be addressed in the lesson, and despite a passionate commitment on the part of the teachers to enhance pupil learning, pupils may still not learn as thoroughly as one might desire and indeed expect. There is a general belief within Learning Study that all children can learn if the teaching act is sufficiently tuned to the topic and the needs of the pupils. There seems, however, there might still remain a deficit even when the key ideas needing to be learnt have been clearly identified. Learning Study theory cannot stand-alone, it needs to relate to a broader spectrum of learning theory which might include issues such as pupils' meta-cognition and peer-based learning as essential ingredients of success.

There is another important point when considering the impact on pupils of the questions asked them in pre- and post-test, in the classroom or when interviewed. The meanings and response that the teacher associates with a question as valid, for example the question "Why?" may not be those naturally identified by the pupils. Why, can have a multitude of possible meanings and responses from the perspective of the child, and in giving a simple word answer they may be conceiving and wishing to convey a much greater body of understanding. Indeed this is what adults do. In using the terms evaporation and condensation we include as "understood" a range of meanings that go unsaid. It is quite possible that children are taking as understood a lot of detail when giving one-word answers to the questions. It is only through additional questioning and interviewing and reading off details in drawings, for example, that we may discover what precisely is being conveyed by any given answer. This realisation is carried forward as we turn to consider the pupil interviews and teachers' discussion.

5.4.2.2.3 Post-lesson pupil interviews and teachers conferences

Three pupils of different perceived academic abilities (high, medium and low as perceived by the class teacher) were selected to be interviewed as a group by the researcher, after the research lesson for each cycle. The purpose was to find out what pupils had learnt in this lesson, that is, the "lived object of learning" of the pupils (Lo, *et. al.* 2005) and to identify the gap, if any, with the intended object of learning. The team, especially the teachers, found the interviews very useful in supplementing the information obtained from the post-test. The teachers were amazed at the pupils' ability in presenting their thinking in explaining the relevant phenomena.

The questions asked in the pupil interview included:

1. What were the main topics you had to learn in this lesson?
2. What activities in the lesson helped you learn these topics?
3. In the test that you have just finished, can you tell me more about your thinking in answering Q1/Q2/Q3/Q4?
4. Why are my spectacles misted up when I step out of the air-conditioned taxi on a summer's day?

The following are some of the responses in the pupil interviews conducted by the researcher. Again, we can see, the answers for class B (with the experienced science teacher) lack details and appear to reflect rote learning. Even so, as just emphasised, the pupils may be intending more than they said. In the pupil response that follow, the letter represents the class (A,B,C,D) and the number represents the status of the pupil's perceived academic ability (1 = low, 2 = medium, 3 = high). Thus A3 means the high ability pupil in class A.

Question 1

In the four sessions conducted, nearly all pupils were able to tell me that they have learnt "evaporation and condensation of water", some with exact scientific terms and some with their own words.

C1 : I know that water can also change to vapour below 100°C.

B1 : We have learnt evaporation and condensation.

D2 : We have learnt that there is water in the air though we cannot see it.

A3 : Water can become less during evaporation. It changes to vapour and goes to the surrounding air.

Question 2

Pupils were very impressed with the activities in the lesson. The comparison between the two test tubes was mentioned in the interviews.

C3 : I know that the sun can evaporate water from the test tube, same as in the wet laundry.

B2 : Water can evaporate below boiling point.

D3 : Both boiling and evaporation can make water change to vapour, but boiling is faster.

A1 : The two test tubes show us that boiling is faster than evaporation, but in both cases, the vapour goes to the air. That's why water is less.

The activity with the ladle was also discussed in the interviews.

C1 : My teacher puts a ladle in the cooler; there were water drops on it when it's taken out, because it's cooler than the other one.

B2 : My teacher said that water could condense on a cooler thing. In the lesson, it's the ladle.

D3 : We have two ladles; we can see water on the cold one, because it's cold. After wiping, water reappears again because it's still cold.

A2 : The teacher used the ladle as a magic stick, water can reappear on it. Water can only reappear on cold thing.

The questions asked, which concerned with scenarios used in the lesson, provided an opportunity for pupils to re-think their learning in the lesson, thus providing important information to teachers on how the pupils learn. Note, however, that the response from Class B (the experienced science teacher) is phrased in terms of what the 'teacher said' rather than in terms of the pupils' own learning experience. Overall, teachers were amazed at the expressive abilities of this group of young pupils. When the post-test cannot give the team a full picture of how well the pupils have learnt, the interviews can provide additional valuable insights.

It was very encouraging to find that the pupils' verbal explanations of the related phenomena on the two concepts taught were rich, reasonable and transferable. Though the result of the post-test showed many pupils did not reach Categories E4b and C4b, the interviews provided a better picture of how well the children had grasped these two concepts. During the interviews, pupils were able to explain in more detail their explanation of the 4 questions in the post-test. The team was particularly gratified that pupils were able to transfer their knowledge from the classroom to their daily life, as revealed in question 4 of the interviews.

C1 : The puddle of water begins to evaporate, because there is the sun.

C3 : Because the can meets cold, then there is water drops.

B3 : The water goes to the air.

B2 : The lid is cooler than the hot water, so the steam on top of the hot water can condense on it.

D2 : The can of coca-cola meets the relatively hotter air and so water appears. Whereas in the glass of hot water, the steam above the hot water met the cooler thing and water drops appear

A3 : The water in the wet laundry disappears because the hot sun changes it to vapour.

D1 : The pair of spectacles is cooled by the air-conditioning in the taxi, so the *water vapour in the air condenses on it immediately.*

B3 : It's like that, I walked out of the restaurant, and I saw my father's spectacles. It's like that.

A3 : The pair of spectacles are a magic stick; it's just like the ladle. Water can reappear on it.

Although classroom observations were passive, teachers were able to make judgments about each classroom activity, in relation to questioning, delivery, and class-work. Post-lesson conferences among teachers provided opportunities for such judgments to be articulated and communicated among observers and the teacher who had just taught the lesson. In addition, post-lesson conferences provide an opportunity for teachers to "learn to see". Each part of the lesson was discussed in detail with reference to pupils' interviews and the post-test responses.

Teachers began to realise that pupils could learn scientific concepts instead of facts. When knowing is viewed as "the way of seeing", learning will imply, at least in part, changing the pupils' "ways of seeing". For example, in the interview following the fourth cycle (3A), pupils liked to use the term "magic stick" to describe the ladle and the pair of spectacles. The team immediately realised that this was closely related to the language used by Ms A in the lesson, when she had referred the ladle as the magic stick which could bring back the invisible water in the air. The impression grew; as she asked the class to suggest what other objects could be put in the cooler to be used as a magic stick.

In the post-lesson conference, teachers were given the opportunity to reflect on their own teaching, in response to their peers' observations. They discovered their own strengths and shortcomings, which they might not have noticed if there was no one else in the classroom, other than their pupils. For example, in this study the teacher who taught the first research lesson felt that she had conducted the condensation part of the lesson well. But her feelings were in fact contradicted by the observers' assessment, of what they saw during teacher-student interactions. Moreover, the post-lesson pupils' interview and post-test results also supported the judgment made by the observing teachers. Pupils were indeed not doing as well as they were on the evaporation part in the lesson. The team helped the teacher to see what she would have not seen by herself. Later she said:

> *I thought my questioning was good in the activity (condensation), but my colleagues disagreed with me, saying that I was clumsy and were not able to lead discussion in a systematic and sequential way... I thought I went through the worksheet smoothly but they criticised me for not using the blackboard, causing pupils troubles in drawing their conclusions.*

It is acknowledged that there are issues in the process of this Learning Study project that need to be further addressed. For example, the questions in both pre- and post- tests require written answers, but for pupils of Primary 3, this seems very challenging. Pupils were thus encouraged to draw their explanations and this helped the team to understand, at least to a certain extent, what pupils wanted to express. We have to admit that the pre- and post-test findings and its data analysis are somewhat limited as empirical evidence, but they were effective as a heuristic, in allowing the teachers to gain some insight into how and what their pupils had learnt, as a result of what they have taught in the lessons, and how to move forward. Information about what their pupils were actually learning had an impact on the teachers' improvement of teaching.

5.4.3 Teacher interviews after the Learning Study

As the final act in the Learning Study process, the researcher interviewed the four participating teachers in April 2003. The purpose was to ascertain the teachers' views on the impact of the Learning Study on their own professional development. The following points were generated from their responses to my questions put to them in the interviews:

5.4.3.1 Teachers' awareness of their pupils' learning

> *TC : They have learnt the process of evaporation, not only the term but the process. Here it involved the change of state of water and they (the pupils) knew. To them, condensation is a new thing; they didn't even*

know the term. Evaporation is better. But children are very smart. They will rote learn the term and tell you. So I pretended I didn't understand and asked them to explain. They would still use my wordings. So I required a girl to give me some cases so that she could explain to me again. And then the rest of the class also understands her case.

TA : We use the post-test, very obviously, the result is very different from the pre-test. The pupils' answers were more concrete and the percentage of correct answers was higher. In the following lesson, we made use of the concepts they had learnt in this lesson to apply to the water in nature. They could grasp the meaning without us talking a lot to explain. Therefore I think I have seen the effect and the impact, because in the past, when I taught water in nature, though not to this class, they seemed not so easy to understand this. This is easy to tell. Because I only concerned the factual knowledge level, pupils learnt but could not apply to their daily lives. At the same time, they had developed higher order thinking in this lesson, able to transfer the knowledge to new situation. If not, how can they learn so well? Just memorising the facts cannot have such an effect.

The above extract of teachers' reflection illustrates the point that the teachers are more sensitized to the way pupils learn. On the whole the four teachers were able to sense the difference in pupils' learning in this lesson compared with past lessons, resulting from the emphasis on the importance of learning the concepts rather than the facts. They were also able to see the impact of this lesson's learning on the development of another concept – the formation of dew, mist and fog. Teacher B has the following reflection:

TB : The learning of this lesson is more in depth, like when we taught mist and dew, especially dew, why are there so much dew in the morning? Now they knew, because we had used the lid on the hot water, the cold can etc.....it was cold at night and the leaves were cold too. They knew the water vapour in the air stopped there.

5.4.3.2 Importance of teachers' subject knowledge

Teacher A, C and D all expressed the importance of a sound subject knowledge base before they could teach well.

> *TD : Learning Study gives me an opportunity of enhancing my subject matter too. Before I thought like the pupils, things condense when meet cold and evaporate when meet hot. Also I could use the examples on the book and tell my pupils. But in discussing with you, I realised I could go further than just "condenses when meet cold". Making comparison with something not cold is so effective. Now I know.*

> *TA : Before, I boiled the water to demonstrate condensation by putting a piece of glass over the steam. It was in the book. When the whole class saw water formed on the glass and could say the term 'condensation', the learning was completed. Now I realise that the critical feature was the invisible state of water that was in the air. It can come out again on any cooler surface. This thinking is so different from what was said in the book.*

5.4.3.3 Learning Study as the process to enhance professional development

When the four teachers were invited to comment on the impact of Learning Study process on their own professional development, all of them admitted that this had provided an effective mean to enhance their role as a teacher. Unlike some other professional development programmes, they found it very practical and said that it could be used in the classroom. Teacher C, the youngest teacher among the four, gave her view of this experience:

> *TC : In the past, when I joined the professional development programme, they were mainly talks, or workshops. Of course, talks and workshops have less impact on me. May be one or two sentences of the speaker have aroused me to think, but may not have direct impact on my teaching. This time when we did Learning Study, we started with something micro, not like those talks mainly on the macro aspect, such as the current trend on curriculum reform. This time I discovered that one very small point, though it seems not very important, it is to the pupils, they may learn it only once in their lifetime. That's the impact on them.*

The curriculum developer, Teacher A, expressed her view with a special concern for the resource implication of conducting Learning Study. Yet she felt that going through the process once could be an effective means to allow teachers to learn from their own practice.

> *TA : I have joined professional development programmes before, including doing some research lessons. I have also participated in an action research project. This time, the professional development aspect is very crucial. We spent so much time sitting together and discussing such small point. I really think that this time is very different from what I have done before. Probably we cannot afford to do it again, but we have learned. We have learnt the methods, which can be applied to other classrooms. Therefore I think to our professional development has had a big impact.*

All the four teachers had different degrees of professional growth in the process of Learning Study, some gain more than others. One very significant person in the team was Teacher B. By looking at the dialogue between this teacher and the principal researcher (transcription provided in Appendix 4) we see a level of self-satisfaction which indicates how difficult it can be to change the views of a well established teacher. He is content with a success rate of some 50% to 70% pupil learning in his class, and seemed unaware that questions ought to be asked about those who did not learn. Nevertheless, on the positive side, he is able to admit that his long experience can cause problems and that his lesson was not as good as a less experienced teacher, because he told the pupils the answer rather than letting them discover it for themselves. Though he did not seem to learn much during the process of the Learning Study, he was nevertheless reflective at the end, and this constitutes reflective professional learning.

5.4.3.4 Impact on teachers' pedagogical practice

In the interviews, one question was asked focused on the impact of Learning Study on their teaching. All of them mentioned the following points in the interviews:

- In future they will not simply teach according to the textbook, but will start with pupils' prior understandings
- The teachers had learned to observe others lessons and were now more prepared to be observed

- They would in future focus more on the object of learning and on how teachers can help the pupils to learn this - the main thing is selecting the appropriate object of learning in a certain topic.

- They appreciated increased collaboration with other colleagues

- The sharing of their work with other colleagues was important and they would like to work with colleagues, not yet introduced to Learning Study.

The researcher is aware that the items mentioned above represent more of a wish-list than a report on what they actually practice. What is clear, however, in this case, is that Learning Study can offer a path for the teachers to carry out their own action research, which, in turn, can provide a means to effective professional development. The comments garnered from the interviews with teachers reported above, followed quickly after the fourth cycle of teaching. The final two stages of the Learning Study, concerned with the teachers' final reflections and the dissemination of the study are reported in Chapter 6.

Chapter 6

Learning Study: Final Reflection and Dissemination (Stages 3 and 4)

The previous chapter provided a detailed account of the first two stages of the Learning Study, which involves three main steps, namely:

1. Deciding on the object of learning,
2. Planning and implementing the research lesson,
3. Evaluating the research lesson.

This chapter will be concerned with stages 3 and 4, which comprises the presentation of the study and its finding by the teachers, plus the evaluation by the External Evaluator. The details of these two stages are given in the following table.

Stage	Date	Empowering activities	Teachers' activities	Pupils' activities
Stage 3	Jul – Aug 2003	Power-point preparatory meetings -11th Jun 2003 -7th Jul 2003	Internal presentation in the project school by the 4 teachers	
		Presentation of the study 14th Jul 2003		
		Presentation of the study 25th Aug 2003	Public seminar to teachers in other schools by the 4 teachers	
Stage 4	Mar 2004	Evaluation by the External Evaluator 23rd Mar 2004	Teacher interview (N=4)	Pupil interviews (N=4, randomly selected from 4 classes 4A, 4B, 4C and 4D)
	Sept 2004	A delayed teacher interview 25th Sept 2004	Teacher interview (N=4)	

Table 6.1 The timeline and activities of the research project in stages 3 and 4

Stage 3, concerned with the teachers' reflections and presentations, is crucial in the process of their professional development, as it requires them to reflect deeply on their practice and account for it formally, in a professional language. Stage 4, includes the evaluation of the External Evaluator for the project and a delayed interview with the participating teachers by the principle researcher, which provides rich data on their professional learning after the Learning Study project.

6.1 Stage 3 - Presentation of the study by the teachers

As described in Chapter 5, the Learning Study completed four teaching cycles with each participating teacher teaching one of the lessons. The post-test results of the four classes were analysed and compared to the pre-test results in the evaluation meetings. The team reviewed each lesson, learned from the pupils through interviews, post-test results and class interaction, and then made recommendations for their future. As a result of this process, the team worked to prepare a staff development presentation session in the project school.

The school principal was eager to arrange an internal presentation done by the four teachers to all the other teaching staff. She had witnessed the amount of effort that these four teachers had put into this study and, as the result of it, the impact on their professional development. This was the first time the principal had ever provided opportunities for teachers to share their professional act with the other colleagues. She regarded this as a "mile stone' in the development of the school as a learning community, in which more teachers would be able to discuss their teaching with their colleagues. The research team then set about preparing a power-point presentation, which they decided should focus on providing evidence of how the pupils learn better. The following points emerged with regard to the teachers' professional learning in this process. Teachers' concerns about this model of professional development are also mentioned.

6.1.1 Teachers as researchers

With a large volume of data in different forms; for example, the video-tapes of the four lessons, the pre- and post-test results and the pupil interviews, the teachers were encouraged to select those episodes that they thought represented clear evidence of enhanced pupil learning. During the power-point preparation process, the teachers had shifted their focus of concern from "how they teach" to "how pupils learn", based on the evidence provided in the pre- and post-test, lesson video clips, and most important of all, the pupils' interviews audio- and video-clips. This proved to be very crucial in the process of professional development whereby teachers became researchers into their own practice informed by their own situational understanding (Elliott, 1993). Only when they had adopted an inquiry stance on teaching and learning, were they able to work within a community of inquiry, generating local knowledge, envisioning and theorising their own practices, and thus interpreting and interrogating the theory and research of others (Cochran-Smith, 2005). Teachers' knowledge can only be made public through conversation with the other teachers about their practices. The creation of public knowledge from personal knowledge, aims to make teaching into a genuine "profession" with a research-base and formal body of knowledge that distinguishes the profession from the layman (Gardner, 1991). The process of Learning Study contributes to the creation of public knowledge, in this case shared between the teachers, in their school. The followings are some comments of the four teachers during the evaluation meetings while preparing for the presentation.

> *TC : My confidence in making a public presentation has grown; in fact I have never had the chance of doing this before.*
>
> *TA : When preparing for the presentation, we need to reflect on our decisions and action taken. It's an important step in our learning.*
>
> *TB : I begin to regard myself as a professional, not a technician in the classroom.*
>
> *TD : The contribution of the Hong Kong Institute of Education academics makes a very big difference to how we think about the lesson.*

6.1.2 The Importance of contribution from the Hong Kong Institute of Education

The importance of the academic contribution from the Institute should not be under-estimated. It takes two main forms:

1. An input to the subject knowledge
2. The research and evaluation element.

6.1.2.1 An input to the subject knowledge

In this particular case, the researcher (acting in her role as a member of the Learning Study team) spent considerable time sorting out the subject ideas of the participating teachers. As already noted, there is a major problem in Hong Kong with subject expertise in science, which was particular evident in this case. But experience of other Learning Study cases in primary science demonstrates much the same point. Often teachers have their own misconceptions and it is by exposing them in the context of doing a Learning Study that teachers become aware of the impact of their own shortcomings. When they are not clear in their own mind about a topic, it is highly unlikely they will present a clear understanding to the pupils. Specifically, in this case, the joining together of evaporation and condensation into one lesson topic was suggested by the researcher, as the result of appreciating a lack of clarity in the teachers' thinking about the topic (refer to Appendix 1, a transcription of the meeting with the teachers when this point was discussed). The key issue was the existence of the water in the air in an invisible state, which the teachers had not fully grasped. Once they had understood that critical feature, the opportunity for enhancing pupil learning was opened up. Though it is not the main aim of Learning Study to discover findings that are generalisable across a large population of teachers or schools, there would seem to be prima facie evidence that if teachers teaching this topic have the same lack of clarity as the teachers in this particular school, and there are good reasons for thinking they might in the context of Hong Kong, the restraints on pupil learning will also be somewhat similar.

6.1.2.2 The research and evaluation element

With regard to the research and evaluation element, the researcher from the Institute brings a research framework for action research into the authentic setting of the school and the classroom. Teachers in Hong Kong often engage in what they call collaborative lesson planning, though in truth, it is often not much more than a discussion about how best to teach the textbook. Even so, their involvement in collaboratively working together and reflecting on their actual practice goes little further than joint planning. The research framework for the Learning Study includes collaborative lesson planning but takes the whole process into a stage where the teachers then act as researcher into their own practice.

In order to follow the framework and use it flexibly, the role of the researcher is pivotal. In other words, one could not hand the teachers a copy of the research diagram showing the procedures and then expect them to follow it themselves. They need constant support and mentoring as they develop their research skills. In regard to evaluation, left to their own devices, the teachers often do little more than attend to surface impressions. For example, having observed a lesson, their comments tend to be quite superficial and they seldom analyse the lesson in depth. The Learning Study process, as pursued by the researcher, requires that the teachers reflect deeply and critically on the extent to which the lesson has achieved the desired learning outcome(s). For instance, teachers in Hong Kong seldom if ever interview the pupils after a lesson to ascertain their understanding of the topic, yet this is built into the process of Learning Study. Teachers are often very surprised to find that what they thought the pupils were learning was not in fact what the pupils were learning. This is captured in the Learning Study process by referring to the intended object of learning and the lived object of learning

As the school principal expected, this very first presentation of teachers' own teaching created opportunities for others to reflect on their own work and see the relevance of the new practices introduced by this study, as one member of the audience noted:

> *Audience* : *The object of learning and the relevant critical features have been considered and teased out so carefully. I think the time spent is worth it.*

Other colleagues commented on the usefulness of lesson observation and how feedback was incorporated into the second cycle. The threat of being criticised when observed by others was also mentioned, but it was recognised that when the focus of the observation is not directly on the teacher, but on the jointly prepared lesson and *pupil learning*, much of the dread of being observed is taken away.

Audience : *It's not easy to be so calm and confident when being observed and video-taped. How can you manage it?*

TD : *The lesson was observed by our own team, everyone involved actively in the planning of the lesson. The lesson is owned by all. So the comments or criticism were mainly concerned with how to help pupils learn better.*

6.1.3 Questions about Learning Study

After this in-house presentation, the team was invited to make another public presentation to other primary school teachers organised by the CLASP. The teachers presented this case study to a large number of teachers from other schools. This meant further distilling their ideas after the first presentation in their own school in July. The audience, who were mainly science teachers, many of whom, one can assume, also experienced difficulties in handling this topic of "evaporation and condensation", were very interested in how the two concepts were considered together in a lesson, and how that contributed to helping pupils understand the whole topic better. They also commented on the considerable time resource put into this study and several of them questioned whether it's worthwhile. The answers from the presenting teachers demonstrated that they clearly appreciate the importance of giving time to the process of learning that had taken place.

TC : *It's worth doing, going through the process is just like attending a course, but this course is learning* by doing.

This appreciation of the need to give time to the process was coupled with an awareness of having gained personally by engaging with the learning study. Though this was only one Learning Study, on one topic in the curriculum, the professional learning was sustainable insofar as it impacted on their understanding of processes that could inform their teaching in the future. They would be much more mindful of the need to clearly identify the precise object of learning and critical feature and how those will make a difference to lesson planning.

> *TD* : *Of course we cannot do Learning Study for each of our lessons, but at least, our awareness has strengthened and the focus on knowing what you are supposed to teach, that is, the object of learning, is important. It provides the direction for the lesson.*

One teacher in the audience agreed with the importance of identifying the critical features.

> *Audience* : *The point you've made about the critical feature is very important. I also teach like that by telling the class that water has disappeared. I am not aware that it's (water vapour) invisible but still exist is so critical. But it's not easy for teachers to do it.*

The teachers involved in the Learning Study responded by referring to the importance of collaboration with higher education. The academics from higher education can provide support in strengthening the research elements by providing findings in other studies in the same topic so that the team could make reference to. The teachers also acknowledged the function of conducting pupil interviews before and after the lesson as in contributing to the knowledge of how well the pupils could and had learnt. One member of the audience asked about the use of the pre-test:

> *Audience* : *Since the pupils had not learnt the topic, the result of the pre-test must be poor, so what's the purpose?*

In fact, this was also a question asked by these four teachers at the beginning of the study. Only when they have gone through the process of designing diagnostic questions, they didn't realise the purpose of doing so. Teacher A and Teacher D gave the following responses:

> *TA* : *The purpose of these questions is to find out the preconception of pupils, their thinking of the concepts taught. It's not the intention of merely making a comparison with the post-test.*

> *TD* : *It's a way to find out how pupils think. We encourage them to*

express themselves, even through drawings in answering the pre-test. Then we can begin our planning of the lesson according to their difficulties.

One common concern of the audience is the time resource put into the study. One of the questions asked was:

Audience : Can we omit the pre and post-test and just follow the steps in the planning of the lesson?

This issue had been bothering the participating teachers too at the start of the study. However, after the Learning Study process, the teachers realised the importance.

TD : The process of conducting Learning Study can build up our awareness of how to help pupils learn. Working on a diagnostic pre-test is one way to understand our pupils. Of course, if you are an experienced teacher, you can always find out which part the pupils cannot learn well but you don't know why...umh.. I think we cannot omit these steps.

TC : May be after doing the Learning Study once, you can make use of the framework to help you plan the lessons.

6.2 Stage 4 – Evaluation by the External Evaluator

6.2.1 Evaluation of the project by the External Evaluator – teachers' perspectives

As noted in Chapter 3, this case was part of a major project, which involved some 40 Learning Study cases across the primary curriculum. It was funded by the Quality of Education Fund of Hong Kong, and known as the Progressive and Innovative Primary Schools (PIPS) Project. As such, the project had an External Evaluator, Professor John Elliott of the University of East Anglia, UK. He produced a report on the project, *The Independent Evaluation of the PIPS Project* (Elliott, 2004), and, in the process of making his evaluation, he visited a number of the Learning Study cases, including this case. In this section, a summary is given of the interviews conducted between the Evaluator, the teachers and the pupils participating in this case, in order to understand more about the delayed effect of this Learning Study to the participating teachers and pupils. The Evaluator visited the school and conducted his interviews in March 2004, one year after the case was completed (March 2003). The interviews were therefore primarily concerned with the recollections of teachers and pupils.

6.2.1.1 Focusing on the object of learning

The Evaluator asked the teachers to describe any differences that they saw in the kind of teaching and learning activities undertaken as part of the Learning Study when compared to their normal practice. One teacher responded, as quoted in the project report (Elliott, 2004, p. 26):

> *I think there is a great difference. Let me try to explain in English. Firstly, in the past, we taught the students in the same way as the book gives the information. We just follow the books; teach the terms and all the things in the books. Sometimes we have some experiments too, but the experiment followed the books. But for this Learning Study lesson, there is a great difference because we have to prepare everything we are teaching. The topic is water. We considered all aspects related to water and then refined the topic to the condensation and evaporation of the water. In the past, students just learnt the books and follow the teachers' guides. Students recited from the books and answered so in the examination papers. Then they got very high marks. We don't know oh.....we just know that students get very high marks and we think that they knew all the things. But after this study, my feeling is completely different because we have the lesson try to guide the children in the way that they really understand, not recite from the books, and not for students who are not very clever but all students can understand what we taught. So I think it is helpful for the students, and we teachers, we understand we should let student completely understand what we are going to teach.*

The teacher was able to break her traditional thinking concerning pupils' learning from the book to provide opportunities for pupils to develop the concepts themselves. The concern has been focused on pupils' learning rather than on her own teaching. Teachers understood the importance of focusing on the object of learning as the guiding principle in the lesson.

6.2.1.2 The importance of knowing pupils' preconceptions and its implication to the idea of assessment for learning

The teachers also acknowledged the diagnostic nature of the pre-test and the usefulness of conducting pupil interview as critical for the formation of good pre-test questions. The interview by the Evaluator confirmed that the teachers themselves had realised how the process of conducting Learning Study helped their professional development. I believe that this was a genuine comment expressing their true feelings and not said simply to impress. One teacher responded to the question by the Evaluator about whether they used the information from the pupil interview in designing the pre-test (p.27):

> *Yes, there are some loose connections. Actually in between the interview and the pre-test they have the pilot test. So, interview, pilot test and then the pre-test. But during the pupil interview, we concentrate on the pupils' concept about the water, the 3 states of water, ice, liquid and gas. Then in the pilot test, we became more focused and refined the topic into the areas of evaporation and condensation. At that time, we set 3 questions on the pilot test. After that we have the pre-test. During the pre-test, there was more vigorous planning on those concepts.*

The importance of "Assessment for Learning" has been reiterated and embedded in the recent curriculum reform in Hong Kong. The pre-lesson and the post-lesson interviews together with the diagnostic test can best serve such a purpose, though the teachers did not fully appreciate this. However, as the Evaluator noted in his report, Learning Study may be "perceived as a praxiology that enables teachers to acquire first-hand experience of educational ideas in action, as a basis for reflecting about the meaning and significance for their teaching" (Elliott, 2004, p. 27). In the interview, one teacher also mentioned that because of the Learning Study, she was more aware of the diversity of pupils' idea/belief about the same object of learning.

> *In the pre-test, for example, even though students get the answer correct. And then in the post-test, you would see that the answer they gave is more detailed and more in-depth. The types of questions in the tests are not multiple-choice questions. It's all open-ended.* (Elliott, 2004, p. 30)

6.2.1.3 Responsibility for the development of pupils' understanding

As the result of going through the Learning Study process, teachers came to appreciate that pupils often have their own lines of reasoning and teachers should listen to the pupils in order to help them develop their understanding.

> *I feel very happy when the students ask a lot of questions with different ideas. Because if they want to ask, that means they want to learn; they want to learn, and I can teach them very happily.* (Elliott, 2004, p. 29)

> *In Learning Study, you can do it in a big scale or a small scale. I fit it into a small scale. I am also teaching English. I found that when I teach tenses, students make a lot of mistakes. Now I am more aware of V1, pupils' learning difficulties. I look at the mistakes and find out why students make these kinds of mistakes, and then I reflect on my own teaching. Is there anything to change in my teaching so that I can help the students to improve? The Lesson Study experience makes me more aware of my own teaching and things I can apply to other subjects.* (Elliott, 2004, p. 31)

The teachers realised that if the pupils could not learn, they have to hold responsibilities. The evidence that pupils are able to learn better may be the motivational force for them to reexamine their pedagogy.

6.2.1.4 Evidence of effective learning of pupils

From the evaluation report, there was evidence that pupils were able to transfer what they had learned about an object of learning from one topic to another. Teachers also noticed that pupils were able to ask questions about phenomena they experienced in everyday life (Elliott, 2004, p. 35).

> *Lesson Study changed my attitudes on teaching. So now after Lesson Study, I became more serious about the contents of the lesson. And because I felt a higher sense of responsibility. For example, like water, there was only one topic and maybe one lesson. Primary students may have only one chance to take that particular lesson. That's all they learn about water, and then after that they may not come across that topic again. So I think that it is important for the teachers to give as many different perspectives of that topic as possible to the students.*

...after the topic of evaporation and condensation, we taught fog and dew. The students understood fog very quickly. They knew this was condensation of vapour when cool air meets. In that Lesson Study, they understood completely-----.In the past, I taught fog-----students didn't understand, because they didn't understand the condensation of vapour. Another aspect is also very important. Students' thoughts were stimulated. They can think on this condensation and evaporation topic, not just from the books. They have the concepts. Their concepts were widened.

In this study, teachers experienced a new way of collecting evidence about pupils' learning, like the pupils interviews. In doing so, this group of teachers could understand their pupils better. They came to realise the importance of helping pupils discern different aspects of the object of learning and to let pupils see the relevancy of the learning,

6.2.1.5 Support from tertiary education institute

Teachers valued the school-based support of HKIEd subject specialists in developing the curriculum at the classroom level through Learning Study. This was important for teachers to acquire the method and the theoretical framework in conducting Learning Study the first time. The support of the HKIEd staff was also seen as important in exposing the team to the importance of pedagogical content knowledge and how it helps pupils' discernment of the critical features (Elliott, 2004, p. 38).

Of course P's role is very important, because she put a lot of input on science knowledge. Among 4 of us, only Mr. Y has a science background. All of us don't. Our level was only as a primary student in science. That is why we acquired a lot of science knowledge from P. The role of P is not here to teach us science knowledge, what P did is to try to use different methods or examples to let us understand what are the critical features for evaporation and condensation.

I think beyond the science and knowledge, the point is, how to make the students understand what we are teaching? It is not just science terms and just the understanding of them. It's what experiments follow on, and how to make the students learn. P helps us a lot. The point is, how to make the students learn this, for example, from the experiments, to make them understand when you use this method, this is more important than the teachers' knowledge on science.

P's role is not only to give the teacher more knowledge about science. But the most important thing is, it makes the teacher more aware of how to empower students to learn, real learning, not just transmitting the knowledge. If we hadn't gone through the Lesson Study and it wasn't supported by HKIEd, we could not have done it ourselves. Actually, Lesson Study or action research can apply to any other subjects. But Lesson Study is not about methods or skills, it is the theory, and the subject knowledge, and the method. Through this Lesson Study experience, we know how to incorporate the theory, the subject knowledge and the teaching method in our teaching.

6.2.2 Evaluation of the project by the External Evaluator – pupils' perspectives

A group of four pupils, now in Grade 4, were selected randomly from the four classes, one from each class and were interviewed together by the External Evaluator with an interpreter alongside him throughout the whole interview process, as the pupils were using Cantonese in response to the External Evaluator's questions. The interview took the form of a semi-structured interview and the whole process was video-taped.

6.2.2.1 Pupils' memory about the research lesson

The External Evaluator began his discussion with the pupils by asking whether they could remember the lesson they had been taught one year previously on condensation and evaporation. It is worth pausing to note that this is not the kind of questions pupils are normally asked, and the expectation might have been that they could not remember the details of the lesson though they may have remembered the details of what they have been taught on the topic of condensation and evaporation. It was therefore somewhat of a surprise to note that the pupils not only remembered the topic but also the lesson. It was something about that lesson that stuck in the pupils' mind. Perhaps that was because of the cameras and the other teachers that were present as observers but from what the pupils said it became clear that they appreciated the lesson because of what they had learned:

We had some experiments in the class. The teacher boiled some water with a fire. We saw some gas come out. (p. 13)

We boiled the water there were some bubbles. When the bubbles evaporated, we could not see the gas. They came out with no colour. (Elliott, 2004, p. 13)

6.2.2.2 Widening of the learning space

When the External Evaluator asked the pupils if they have asked their teachers questions about evaporation and condensation, most of them said yes and could still remember the questions asked (Elliott, 2004, p. 14)

I asked the teacher why there was condensation on the leaves of a tree in the evening. But both the air and the trees were cold at night.

I asked when we have an ice cube, why does the water vapour not condense on the ice.

The content of the responses illustrated that the pupils showed great interest in the lesson and were also encouraged by the attitude of the teachers, to provide them with a bigger space in learning. The organisation of the lesson also instilled in the pupils a feeling that this lesson is a different one.

There were more experiments, more fun. It was more interesting and easier to understand. (Elliott, 2004, p. 15)

Some pupils even remembered they discussed this topic with the parents at home. (Elliott, 2004, p. 24):

I discussed more about this topic with my family. I told them the experiments and the results.

I explained to my mom that this was what we had been taught,

I told my parents what I had learned and they understood better what happened in the class.

When the External Evaluator asked them whether the learning during this lesson was deeper, or if they were able to transfer their understanding to later topics, the pupils held the following views (Elliott, 2004, p. 22):

Yes, it helped me with the topic 'fog'.

Yes, but the teacher could go through it more quickly. And we could understand it better.

Teachers didn't need to repeat or design extra activities to explain.

The above conversation shows that the pupils thought this lesson was different from their previous learning experience and had a positive impact on their learning.

6.2.3 A delayed teacher interview

It was nearly one and a half year after the completion of the study (in September of 2004) that the researcher went back to the school and met the four teachers, individually. The intention of the meeting was to find out the impact of the project on their teaching and professional learning. I also wanted to meet them individually, so that we could have a more in-depth and genuine discussion. I tried not to intervene in what they said, so they could continuously share with me their own thinking. Below is a transcription of what they said:

TA:

As the curriculum developer in the school, I think I am very lucky to be able to make use of this framework to help my colleagues. The pattern of variation was very useful in helping us to plan meaningful activities. I have to thank the other three colleagues who have contributed a lot in sharing their work with the others. I believe the motivational force that makes teachers work so hard is the value of collaboration. After this year, my belief in the effectiveness of conducting research lessons has increased. We have found our way forward. Besides doing it in General Studies, we also start in other subjects such as Mathematics and Chinese. It is hoped that our pupils can learn better because teachers are sensitised to their needs. I am grateful to this project; it's a good start for us.

TB:

Participating in this project a year ago has changed me. Being a teacher of over 20 years, I always thought that I am already a good science teacher. Not until I saw the others' classrooms.... The collaboration and the learning that has taken place throughout the process have made me so joyful. This joy cannot be found elsewhere and I will remember. I am still creating this joy now in my classroom.

TC:

After the Learning Study, we have become comrades and I found that I was not alone anymore. Though my teaching experience is rather short, compared to the others, I think that I have advanced tremendously. In the beginning of the project, I have questioned about the resources contributed in preparing for a fifty-minute lesson. I know the answer now; to the pupils, they have experienced a fifty-minute lesson, but to us, it's a six-month professional training. It's a short cut for my professional development. Without going through the process of Learning Study, it may take a longer time for me to become a competent teacher. My gain is not only this fifty-minute lesson. This experience has deeply affected my teaching – to start with my pupils. It's how they learn that matters. I am very aware of finding the appropriate and worthwhile object of learning, even in the other subjects. I have learnt a lot from this project.

TD:

I still remember the feeling of unity at this moment. I tell you, though only one teacher was teaching in front of the class, I regarded myself doing the teaching too. I was so keen to find out what they have learned, and of course, what they have not learned. This kind of feeling can only exist when we work so closely together – we own the lesson together. Now, we are trying to do the same with the other teachers. Though we are very busy but how to make it more worthwhile? How to understand what's in pupils' mind in order to help them learn better? Our pupils have their own needs and that's why school-based curriculum is important. We have to acquire this ability. I think this is the most important thing for teachers to do. As the panel chair, I encourage the other colleagues to plan their lessons using Variation Theory. I know it's difficult but I am trying. Four of us are the seeds now.

These delayed interviews showed that the months of working together with teachers were an effective means of school-based professional development. The four teachers involved in this project had shown different levels of professional growth. But one thing in common about their learning is that they were sensitized to the need to focus on what pupils should learn and how to bring this out in the lesson by making use of the patterns of variation. Another significant impact on teachers' learning is their ability of developing school-based curriculum, an important aspect in curriculum reform.

Chapter 7
Conclusion

In Chapter 5 and 6, the Learning Study case has been considered in detail and its various strands have been teased apart. The role of the principal researcher in this Learning Study was as a participant observer, acting as a member of the school-based research team and bringing subject and procedural expertise to the school-based project. However, the researcher played a second role, at a meta-level of analysis, removed from the practice, investigating the extent to which the Learning Study was able to provide professional development for the participating teachers and the implications this might have for further teacher development in Hong Kong. This concluding chapter will be concerned with this and related issues. Specifically, it will include the reflections by the researcher on the Learning Study model related to the three main research questions, a consideration of the limitations of this study, plus the recommendations that emerged from this study.

7.1 Discussion of findings

7.1.1 Teacher professional development

The short answer to this question, as evidenced particularly in Chapters 5 and 6, is that the empowerment of the teachers in this case was certainly significant. That is not to say that the teachers were perfected, but that they became much more aware of their own practices and how these impacted on the pupils' learning. From my perspective as a researcher, bearing in mind the comments made by the teachers to the External Evaluator and myself, which occurred around a year after the Learning Study, it does seem that the Learning Study model provides a comprehensive platform for teacher professional development. From this research project, we see this happening in the following five ways:

1. Learning Study permits a professional dialogue among colleagues

During the Learning Study cycle, teachers met regularly over a period of about six months, to clarify about the object of learning of the research lesson, and to teach it. As every teacher in the group had to participate in the teaching of the lessons, the discussions were always fruitful and dynamic. Each teacher had his or her own contributions to make, by sharing previous experiences in teaching the topic and in the post-lesson conference, where they shared their observations on the complexity of the lesson. In particular they came to realise that their teaching act is not synonymous with pupil learning, they may teach but pupils still not learn. Pulling together their experiences and ideas proved to be crucial in researching and teaching this lesson. Teachers recognize that they must work together to achieve their collective purpose of helping pupils learn better. Thus, Learning Study creates the structure to promote a culture of collaborative planning and analysing lessons among peers. This is very important in the Hong Kong context, where teachers frequently exist and work in isolation from their colleagues. The Learning Study permits professional dialogue in ways that would not normally occur in Hong Kong schools

2. Learning Study enhances collaboration with tertiary institutions

Learning Study provides a context for academics from tertiary institutions to work closely with frontline practitioners in schools. Both parties interact in various ways in the learning process. The teachers are experts in their own classrooms and pedagogies and colleagues from tertiary institutions are experts in the additional subject knowledge they bring to the Learning Study in its theoretical framework. Through professional dialogue, both parties gain in professional understanding, teachers may gain their subject knowledge and all gain in better understanding of how pupils learn, through engaging in an authentic classroom learning situation. When the dialogues are focused on what pupils should learn, teachers are able to reconceptualise their roles as curriculum developers, not merely a technician giving instruction in the classroom.

3. Learning Study encourages teachers taking an inquiry stance

Teachers and academics start to plan the lessons by inquiring into pupils' prior knowledge of the topic by making use of a pre-test. The analysis of pupils' conceptions helps the Learning Study team to select a worthwhile object of learning. The team proceeds to discuss and identify the critical aspects required to understand the object of learning. The lesson is then planned and taught making use of patterns of variation (Marton and Booth, 1997) as pedagogical tool to help pupils to discern the features of critical aspects. The Learning Study cycle provides the venue where every person in the team contributes their expertise to each cycle. The lesson is reviewed, analysed and revised before it is taught again. Such a feedback loop does not only bridge the gap between research and classroom teaching but also allows teachers to adopt an inquiry stance through critically viewing their own teaching. Although an inquiry-based stance adds a layer to the teaching making teaching more complex and difficult, the documentation of the process serves to enrich teachers' knowledge base.

4. Learning Study opens up opportunities for multiple means of dissemination

Public presentations of each Learning Study case are arranged. These are conducted at three levels. The Learning Study team first presents the case in the participating teachers' own school. The second level is a presentation to other schools on invitation. At the third level, the team presents their case study in public seminars organized by the Centre of Learning-study and School Partnership (CLASP) of the Hong Kong Institute of Education. These three occasions provide the channels for the work of individual schools to be disseminated and networks to be formed among the participating schools. As was clear in this case, teachers were able to articulate the theoretical framework of the study and present an analytical account of the research lesson, in all of the three levels above. In doing so, they gained additional insights into the project they had been engaged in. Hopefully, as a result of engaging in the study, teachers will begin to see themselves as researchers, able to systematically record their work and create a collective practical knowledge base.

5. Learning Study opens up opportunities for teachers to reflect on their own practices in a more systematic way

The Learning Study provides a context for teachers and researchers in the field to sit together and discuss teaching and learning in the classroom. Even more important is that the discussion is based on a common theoretical framework, *The Variation Theory.* This framework, which was discussed in Chapter 4 and its implementation recorded in Chapter 5, provides team members a common language and focus to explore pupils' learning, and this has implications for how teachers teach. Thus, through this kind of professional dialogue, teachers understand more about their own teaching and are more sensitised to pupils' needs. In the process, a difference in the content of teachers' dialogues is discerned, in that their concerns have shifted from using varieties of teaching strategies in class to an in-depth understanding of the critical aspects of the related object of learning. This is no easy task; teachers have the competence to make such identifications but it is just that such knowledge is not fully reflected on and made use of in bringing about learning. Learning Study provides a context for teachers to dig into this unique area, and this enhances their role as professionals in the field. Teachers are no longer tied up with technical issues of using appropriate strategies to teach, but become aware of the development of pupils' conceptual understanding, thus moving from techne to praxis.

7.1.2 Teaching linked to learning

Throughout chapter 5 and 6 we saw time and again how often the teachers' professional development came about as a result of their grappling with the problems of pupil learning. Form the pre-test, post-test and pupil interviews, they were alerted to the pupils' learning difficulties and how these often resulted from problems of teaching. One key example that emerged was the way in which the teachers grew in their professional understanding when they realised the difficulties the pupils were having in grasping the idea that the water vapour becoming an invisible part of the air. But this required that the teachers also understood this phenomenon and in fact they didn't. So, in this instance, the professional learning of the teachers consisted of subject learning, and pedagogical content knowledge; understanding the phenomena, and understanding how best to convey the concept to their pupils.

7.1.3 Enhancing pupil learning

Results of the pre- and post-test when compared demonstrate across the board that pupils advanced in their learning. However, there are two important points to be made about this observation. First, there is nothing exceptional about pupil learning after having a lesson. That is the purpose of every lesson. The fact that the pupils cannot understand the concept before the lesson and then understand it much better after the lesson is what one would expect. What needs to be shown is that as a result of engaging in the Learning Study, they understood it significantly better than when the topic is taught normally. However, no such data exists and so that inference cannot be made. The second point is that within this case not many pupils managed to achieve the top level of understanding, which is the one that might be called the "scientific view" of evaporation and condensation. These are two important caveats to any claims that might be made about how and to what extent the Learning Study is able to change pupils' understanding. However, what can be said is that there was sustainability in pupils' learning over the period of one year between the teaching of the lesson and the visit of the External Evaluator. As we saw in Chapter 6, pupils not only retain their understanding of the topic but also their memory of the actual lesson and its' many activities. In fact, it could be said that the pupils' retention one year later and their understanding of the concept was greater than it was at the time of the lesson, as revealed in the post-test. There are two possible and important reasons why this might be the case. First, it is now being recognised that the human brain requires a period of time in order to consolidate long-term memory. Second, the pupils' learning in the research lesson was subsequently carried forward into other lessons on related topics such as the "water cycle" and "fog, dew and mist", where the understandings gained in the research lesson would be reinforced in the subsequent lessons.

7.2 Limitations of the study

The main limitation that applies to this case study are those that applies to any case study. It is a singular case conducted in a particular setting with a particular group of participants where the sample of those involved is small. The case study approach is not designed to provide quantitative data that can be applied across the board to all samples of pupils and teachers universally that is not its purpose. What it is able to show is what happens in a particular case under consideration, and in this case; a number of qualitative conclusions about the relationship between teacher's professional practice and pupil learning could be drawn. The findings of this case study, therefore, are in principle restricted to this case. Nevertheless, there is one commonality in this case, which applies generally across in Hong Kong. That is, primary science is taught as part of General Studies and many of the teachers teaching science have poor subject knowledge in science. It can therefore be assumed that in so far as this applies to other schools in Hong Kong, the findings of this study concerning the need to improve teachers' subject understanding if their pupils are to gain understanding, would seem to apply generally.

Another very important limitation of this particular study relates to the issue of evidence. The Learning Study process does not incorporate a control group into the process. There are a number of reasons why this is not done in the context of Learning Study. But what it means is that one has to be extremely careful about claims being made for the success of Learning Study process. For example, as mentioned in Chapter 6, the involvement of the researcher from HKIEd plays an important role in the whole Learning Study process. Cynics might well argue that it is the teaching ability and subject knowledge of that researcher which is making the major contribution to improve pupil learning and not the Learning Study process. Pupils are suddenly provided with an expert teacher and with lessons that are clearly different from their normal lessons in that they are being filmed and observed with a great deal of flourish and show, so perhaps it is hardly surprising that pupils remember the lesson and learn what they are meant to learn. Who would not learn in such a setting with such an excellent teacher guiding the process? In response, however, I would want to argue that this is only a partial assessment of the reality, because the Learning Study provides a very clear framework within which *the teachers as a whole* are able to reflect on and plan the lesson and it provides a means of tying pupils' prior learning and understanding to the lesson content. Moreover, the notion of the object of learning and the critical features that have to be acquired in order to learn the object of learning provide the lesson planning with a very clear focus. It is these aspects of the process that are particularly important to the professional development of the teachers.

This study, by linking the two concepts of evaporation and condensation together has shown certain success in helping this group of teachers and pupils to learn. These concepts are difficult for young children. I am aware of the difficulties of probing into children's understanding of these difficult concepts, making use of the open-ended questions in the test and the interviews. Johnson and Gott (1996) raise the importance of maintaining a "neutral ground" between researcher and child in uncovering the child's ideas during interviews. In other words, researchers should avoid putting words into the children's mouth. Though aware of this point, I have to admit that sometimes it is unavoidable for it to happen. Also, this study faces the challenge of interpreting the children's ideas in the process, when considering the impact on pupils of the questions asked them in pre and post-test, in the classroom or when interviewed.

7.3 Recommendations

7.3.1 The primary science curriculum in Hong Kong

This study has highlighted a major curriculum problem, which has been known to exist since the implementation of the General Studies curriculum in 1996. There is a major deficiency in teacher's understanding of science and this inevitably impacts on their pupils' understandings. It is the recommendation of this study to make primary science a separate subject on the curriculum, instead of offering it as part of an integrated subject.

7.3.2 The teacher education programmes in Hong Kong

At present, most of the General Studies teachers are in fact not coming from a science background, as Teacher A, Teacher C and Teacher D in this case. This is a common practice in Hong Kong primary schools. As seen from this study and many other studies worldwide, there is a direct correlation between teachers' subject knowledge and pupils learning. Besides the recommendation of making primary science a separate subject in the curriculum context, there is also the need of reviewing the preparation of teachers. Teachers of science need a strong subject background. Reconsidering the initial and in-service teacher education is necessary.

7.3.3 Making use of Learning Study for teacher professional development

7.3.3.1 In-service professional development of teachers

The Evaluator in his report (Elliott, 2004) commented that to implement Learning Study across a whole school on a continuous basis is not feasible under the prevailing organizational conditions in schools. Though given the above positive aspects of using Learning Study as the platform for professional development of teachers, there are certain issues to be considered before implemented in schools. The participating teachers should be well prepared before initiating the study. They should be made aware of the workload implication resulting in engaging in the Learning Study. If possible, school principals should facilitate teachers by reducing their teaching load. This, of course, implies an issue of financial funding required. Whether Learning Study should happen because of funded projects or as a means of systematic organised in-service professional development of teacher funded by the EMB still needs to be explored.

7.3.3.2 Initial teacher education programmes

Currently within the initial teacher education there is no provision for students to undertake this kind of action research when doing their practical work in school. If we want to introduce this practice to teachers, we have to start with the teachers-to-be. In Hong Kong, student teachers are in school for teaching practice, which means teaching the normal subject lesson by taking over the existing teachers' lessons. From September 2007, a Learning Study module of thirty contact hours will be offered to all Bachelor of Education programmes in their second year of study in the Hong Kong Institute of Education. The implementation part of the research lesson will be carried out during the School Attachment period when student teachers go out to school one day a week over a period of ten weeks. Hopefully this will go someway towards bringing action research dimension into the initial teaching education of teachers in Hong Kong.

7.4 Conclusion

This study shows that each of the participating teachers demonstrates different extent of professional growth. They were sensitized to the importance of pupils' prior understanding in planning the lesson. We have noticed earlier from the External Evaluator, there seems to be a sustainability in the *product* of Learning Study, however, there is the real question of the sustainability of the *process* of Learning Study. This may be the major weakness of Learning Study. My own reflection of this case, however, is although it is always difficult to enhance teachers' practice, Learning Study might well be a way forward. Hopefully, a change of practice happens after teachers' reflect on their practice, and perhaps this can be sustained and applied to teaching of other lessons. As Teacher A pointed out in her reflection, it is impossible for teachers to treat every lesson as a Learning Study case. However, this case demonstrates that the teachers' awareness of subject and pedagogy was not only raised, it stayed with them, to be carried forward into future lessons to benefit pupils' learning and their own professional self.

In this study, three pupils from each class were selected for interview by the respective teacher according to their perceived academic ability: high, medium and low. The purpose of selecting this sample was to provide a window on pupils' learning across the ability range. It was not, however, used as the basis for further investigating the impact of Learning Study on each of these groups of pupils in detail, to determine whether the advances in learning were proportional across the range. Whether, that is, the value added component of learning was the same or different for each group. Claims have been made that in one particular Learning Study case, the added value was greater for the lower ability pupils than for the upper ability pupils (Lo, *et al., 2005*). This may be one of the areas needing further investigation in regard to future Learning Studies in primary science.

- THE END -

Appendix 1

Transcription of the 3^{rd} regular meeting on 16^{th} Oct 2002.

R: Principal researcher

TA: Teacher A

TB: Teacher B

TC: Teacher C

TD: Teacher D

(P1 - low ability; P2 – medium ability; P3 – high ability)

R : Hello, everyone. Thanks in being so prompt. I understand that everyone is busy, even after school.

TA: Oh, it's our duty to be punctual.

TD: Yes, we are grateful that you can come and work with us.

R : I have interviewed the three Grade 4 (previous year in Grade 3) pupils. We can look at the result today.

TB: We are very anxious to know the result.

R : They were very good in memorizing the process of changes of states; they could provide the four terms like 'freezing', 'melting', 'boiling' and 'condensing'.

TA: Yes, we set the examination paper and they had to fill in the words.

TB: I made this point very clear in my class, it's important that they should know how to write those terms.

R : In fact, not only the terms. All of them could also tell me that say freezing, is to change water to the solid form and we need to put it in the freezer, which means a cold place...and the solid ice can change back to water when at room temperature...they didn't mention room temperature but said when taken out.

TC: We had done this experiment in the lesson last year. That's why they could remember more easily.

TD: They must have this experience at home too.

TB: Yes.

R : Did you boil the water in the lesson last year?

TA: Yes, we started with the ice from the freezer, put it in the beaker in the classroom. After all the ice changed to water, we used a flame to heat it up until the water boiled, having steam come out. Then we put a piece of glass near to the steam so that they could see water drops condense on it.

TB: I took the gas stove back to do this experiment. During the demonstration, I kept asking the class to repeat aloud the name of the processes, like 'boiling', so that they could remember. It could also help them pay attention in class.

TD: TB is so kind, he always solves our problems about the experiments listed in the textbook.

R : So you all thought that this demonstration could help the class understand the concepts of the change state of water?

TB: I have tried this for all my classes in the past years…it's (the set-up of this experiment) also in the textbook.

TA: My class liked it. It definitely was more interesting for them.

TD: My class liked the activity too. They did well in the examination about this topic. I don't think they have any problem.

TC: That's why we want you to help us teach the topic " The formation of mist, dew and fog."

R : Do you want to know more about the result of the interview first? In the interview, I have asked the three pupils one question, "where has the water gone after boiling?" The answers were interesting.

TA: Oh.

R : P1 thought that the water disappeared because it simply disappeared. The other two, P2 and P3 said it went up to the sky and became clouds.

TC: Ohm…we have not discussed your question in class.

TA: Yes, we showed them the diagram of the "water cycle" in the lesson; they must have got the thinking there.

TB: But is it wrong? Is it?

R : What do the others think?

TD: (whispering) I think it's correct…

TA: Have we missed anything?

TC: Boiling is the change of state from water to gas, so, that is it.

R : Thanks, TC. Yes, this is a change of state. Where is the gaseous state of water after boiling?

TA: We have not discussed about this in our class.

TD: The book has not raised this point.

R : I also asked about the disappearing of the puddle of water on the playground. Same responses- to the sky and this time to the sun too. They could relate this to the effect of the sun but didn't know how they were related.

TD: I myself have never thought of this, where has it gone?

R : Simple, it has not gone anywhere. It still exists in air but in the invisible gaseous form.

TB: I know it's the gaseous form.

R : But the important point is that the gaseous form is invisible, so nearly all pupils would think that they didn't exist. TB, you must know the concept of the conservation of matter.

TB: Yes, I know.

R : Can you explain to them what it is?

TB: Matter cannot just lost or disappear.....but I have not made use of that in my previous teaching. I have not thought in such direction.

TD: That's a very good point....I don't think I realise this before.

TB: But we only need to teach our pupils the three states of water.

TA: I think we can teach more, or else our pupils could not make use of it, like in the case of the puddle of water.

TD: I thought I have made myself very clear in the lesson, but may be I have not touched on the concept.

TC: I have never thought of the need to go further after showing them what the three states are. In fact, it's my question too.....where has the water gone after they disappeared? I have never thought of this as so important. I think the key thing to understand this, is water continues to be water....though it has changed state.

R : That's a very good point, thanks to TC who reminds us of this. I think we have to make it explicit in the lesson. We have to remember this point in the design of the lesson.

TC: Your interviews are very important.

TA: To me, science teaching is always difficult; talking to my pupils is a wonderful experience. I am happy to find out how they think, and how I think too.

TB: After telling the class the facts, they should be able to remember…….(utterance) may be they have forgotten.

TD: I am a learner in the process too. I am able to realise that water has not changed to air….it's confusing to say that it has changed to air, but should be the gaseous state, right?

(Note: in Chinese, air and gas bear the same translation)

R : I think teachers should be very precise in the use of terms. It can easily cause confusion or even misconceptions.

TA: We have to know it first. That's why I always think that science should only be taught by science experts. We always approach TB when we have anything we don't know.

TD: That means we have not taught our classes well last year.

TC: Of course, I mean the questions you asked, we have not discussed at all in class. We did not teach like that.

R : It's good that we find this out, this is the way we can improve our teaching. May be we will see what's the response of the three pupils for condensation.

TB: This is easy. My class could tell that steam condensed on the piece of glass when it came out from the boiling water.

R : That is a different context with the cold can I showed them in the interview. P1 told me that he thought that the water is from the inside of the can without explaining why. P3 said that the water was from the refrigerator. P2 agreed with P3 and said that because the refrigerator was cold. P3 explained that when the can was not from the refrigerator, it would not have water on it.

TC: Oh, isn't it the same as the research paper you've given us? Children think like that. I forgot how I thought about this when I was a child….may be I have never thought of it, I did not bother to think when I was young.

TD: I thought of it when I was at Grade 3 to 4. I related it to the coldness of the refrigerator. I have not thought of where the water came. I have taken things for granted.

TB: I know it is condensation, but just that we have not explained in such details. It's not required in the textbook.

R : What do you think, TA?

TA: I am thinking about my own experience. I think it is common sense, but why didn't the children ask us? May be they thought they have learnt.

R : What is missing in the whole concept?

TC: Where does the water come from? It's very important.

TD: I agree.

TA: Where does the water come from then? We need to be clear.

TB: It is in the air.

R : Do you think we have to discuss this important point to the class when we teach condensation?

TC: Oh. I think when we teach this concept, we have not related this to phases change.

R : What do the others think?

TA: Yes, we keep asking if they can see the water on the piece of glass and then stop at this point.

TB: This is too difficult for aged 8 pupils.

TD: But we are teaching phases change.

R : We can bring about a deep learning in the pupils. How can we do that?

TC: There is water in the air, right? May be this is important. In gaseous form.

TD: Yes, this is very important. I am just like my pupils. I myself have not thought of water vapour around us. It's here in the surrounding air. Young children only believe when they can see.

TA: So how can we bring about this point?

TB: It is very difficult as it is an abstract concept.

R : I know it is not easy. But we can try to make learning possible. How about start with evaporation first? And then followed by condensation? May be we can think of how to help pupils to discern this critical feature.

TD: Yes. It is a clever way to do. Just like a cycle., water, water vapour and water again.

TA: That's a good idea. I think this starting point is crucial. If we start, say with evaporation, then we can ask where the water has gone.

TC: Yes, then we can tell that the water has gone to air, but only it is now invisible. Then we will use the cold can again.

TD: But the cold can, may cause confusion. Some may still think that the water leaks from it. How about use something different, something that has got no liquid inside.

TB: How about using a piece of iron?

TA: But you will not put a piece of iron inside the refrigerator, it's not natural.

TC: That's very unnatural.

TD: Why not put a metallic plate or things made of metal, some kitchen utensils?

R : Good that you all are considering of what to use to aid your teaching. That will be our direction forward. But we can interview the Grade 3 pupils next week to confirm our thinking. Can you arrange this for me? I will use the same questions. I can do it next week. Let us find out how this group of pupils thinks before we confirm the object of learning and the critical features.

TA: I will arrange this interview for you.

R : Thank you.

The meeting continued for another fifteen minutes discussing about the necessary administrative arrangement of the next pupils interview.

Appendix 2

The pilot test (in Chinese) given to 12 Grade 3 pupils

1. There is a puddle of water on the playground. After sometime, what will happen to it? Why?

2. When we use a wet cloth to wipe the blackboard, after sometime, what will happen to the water mark on the blackboard? Why?

3. When a cold can of coca-cola is taken out from the fridge, what can you see on the outside of the cold can? Why?

4. When we hang the wet laundry out for a day, what will happen to the laundry? Why?

5. When a lid is placed on a glass of hot water, after some time, what can you see on the lid? Why?

6. When we open the door of the freezer, we can see some white fume? What are they? Why is there this white fume?

Appendix 3

The pre- and post-test given to the four classes 3A, 3B, 3C and 3D before and after the research lesson

1. There is a puddle of water on the playground. After a while, the puddle disappears. Why?

2. We hang wet laundry under the sun. After a while, the laundry dries up. Why?

3. We take a can of soft drink from the fridge. After a while, there are water droplets on the surface of the can. Why?

4. We put a lid on a mug of hot water. After a while, there are water droplets on the surface of the lid. Why

Appendix 4

Transcription of interview of Teacher B on 10th of April 2003

R: Principal researcher
T: Teacher B

R Can you tell me what do you want your pupils to learn in this research lesson?

T Of course. We followed the learning objectives, hoping to let pupils know that water becomes steam, not only during boiling but also at room temperature. Water can evaporate. There are many examples in their daily life experience, such as the wet laundry or the puddle of water. This is evaporation.

R What else have you taught?

T Besides this concept, we have to let pupils know that water vapour existed everywhere. Not only when boiling water.

R We have also talked about condensation, right?

T Yes, besides evaporation we have another objective. This is to let pupils know that the evaporated water is still in the air. How can we make it condense and become water again?

R Do you think your pupils have learned, and how do you know that they have learned?

T I believe so. I think at least 50%, or at least 60 to 70 % of my pupils have learned.

R But how do you know?

T First, from the answers they gave in the lesson. Second, from the post-test result. Nearly 70% of my class knew the answers.

R Can you tell me examples of pupils making use of what they learned in this lesson to other lessons?

T Like water in nature. They knew that water evaporated, rose up and condensed again to form clouds. Rain came down when the clouds became heavy.

R What else?

T The learning of this lesson is more in depth, like when we taught mist and dew, especially dew, why are there so much dew in the morning? Now they knew, because we had used the lid on the hot water, the cold can in the test etc.....it was cold at night and the leaves were cold too. They knew the water vapour in the air stopped there.

R You have seen that pupils' learning of this lesson was effective, why?

T Because I have used a different teaching strategy.

R What teaching strategy have you used?

T Like doing experiments, for every step, I kept asking them.....

R So it was not like this before?

T Before when we did experiments, we just told them what we could see from the experiments. But in this research lesson, we have a different strategy. Every question was pinpointing at the content.

R But you also asked questions in your lessons before, right?

T Yes, I asked a lot of questions. Mainly after the experiments, also I allowed them to observe and then I explained. But these procedures were not as effective. So I normally told them myself rather than them asking. But it was not like this lesson.

R So do you think you are adopting a scientific investigative approach in your teaching?

T Of course. Mainly we will allow pupils to do experiments, make prediction and then get the conclusion. This is related to science teaching.

R That is objective testing...

T Yes, it's different from reading the book.

R You have taught the topic 'water' in previous years, right? Any different in your teaching strategy compared to this year?

T Of course. Especially in General Studies, when there are experiments, we will definitely do them. But the way I ask questions is different. We have had no time to plan the lesson in such details. We have to know the subject before we can teach well. In Learning Study, we analysed every small point and tried to let our pupils use their minds. That means letting them think more. Before, the book fixes everything, teaching is like that, and the experiments are like that and so that is it. This time is not the same. Our pupils are provided with an opportunity to think.

R We have only dealt with a small point. Does it make a difference to your teaching after Learning Study?

T Yes. Like the topic on 'plant'. We have already planned to buy some seeds and ask the class to grow. In the past year, we only gave the pupils a seed and let them take it home without following up the result.

R Why do you want them to do so, I mean ask the class to grow the plants in school?

T First, they can know how plants grow. Second, what else? One of the important topics is 'Plants and our lives'. Why do we need to eat plants? What are their uses? Which parts of the plants we can eat? This year, we require them to do a project so that they can have a deeper understanding of the uses of plants.

R I am interested to know how you find the lesson observation part of Learning Study. Have you observed your colleague's lesson before?

T Yes, we started this practice two years ago. We also used this as a means of appraisal.

R Any difference in the way the lesson is observed and analysed?

T Very different, not the same. First, we do not only pay attention to whether this lesson has achieved its objectives or not. We also pay attention to the pupils. In the past, they dared not move if so many people were in the room. They seemed to be very nervous.

R Do you think that the pupils were not nervous this time, with the cameraman around?

T Yes, no threats on the side of the pupils. May be they were very focused on their learning. I can tell you, it also solved the classroom management issue.

R When you watched TA, TC and TD teach, what was your focus?

T I am interested to find out what the differences were, since the topic was the same. While I was watching, I kept comparing their teaching to mine. TD had taught different from my lesson. We were able to make improvement based on the previous lesson. It was very important. So the lesson observation was on how to improve the learning…

R You have participated in this Learning Study, how do you find it?

T I think it helps me a lot. Though I have been a teacher for over twenty years, this is a chance for me to improve myself. I have to admit that I am very confident of myself. I think I know everything, not like the other three teachers. But when I observed TD's lesson, I was very impressed. She is not a science teacher but her teaching was better than mine. She allowed pupils to find out things for themselves. This should be better than my telling them the answer. I think it should be so.

R Any impact on your professional development?

T Of course, it helps a lot. The most distinct difference is we are more willing to share our practice with other colleagues. This is useful if we have to teach some difficult topic, like 'H.C.F. and L.C.M.' in Mathematics. We can explore the many ways that can help our pupils learn better by sitting together and discussing. Pupils can learn better and in a more orderly manner. I think the value is here.

R But doing Learning Study takes up a lot of teachers' time and effort, any suggestion for improvement?

T I believe there must be somewhere we can improve. Working alongside with you is crucial. Maybe we are not familiar with each other at the beginning, so it takes more time. Maybe doing it the second time does not need so much time.

R Thank you.

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