Science is Primary
Children Thinking and Learning in the Chemistry Laboratory
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Abstract

The goal of primary science education is to foster children’s interest, develop positive science attitudes and promote science process skills development. Learning by playing and discovering provides several opportunities for children to inquiry and understand science based on the first-hand experience. The current research was conducted in the children’s laboratory in Heureka, the Finnish science centre. Young children (aged 7 years) which came from 4 international schools did a set of chemistry experiments in the laboratory. From the results of the cognitive test, the pre-test, the post-test, supported by observation and interview, we could make the conclusion that children enjoyed studying in the laboratory. Chemistry science was interesting and fascinating for young children; no major gender differences were found between boys and girls learning in the science laboratory. Lab work not only encouraged children to explore and investigate science, but also stimulated children’s cognitive development.

Keywords: science centre, children’s laboratory, cognitive development, learning by playing, learning by discovering, inquiry-based learning, science process skills.
1. Introduction

1.1 Heureka, the Finnish Science Centre

Heureka, The Finnish science centre was located in the city of Vantaa in Helsinki metropolitan area. It was opened to the public on 28th, April 1989. Now 16 years passed, Heureka has become a well-known institute in Finland.

Heureka is Finland’s largest and one of the world’s leading science centres. Heureka’s permanent hands-on exhibitions are grouped into clusters: thought and mathematics, the universe and the laws of nature, the changing environment, the open laboratory, the global village, language and cultures, energy and production, children’s Heureka. Two temporary exhibitions are developed every year. Between 1989 and 2004 the exhibitions have been seen by 13,962,819 visitors both in Finland and abroad.

There are a planetarium, science theatre, basketball rat games, science park and two laboratories in Heureka. In Verne Theatre visitors can enjoy many interesting super-films and planetarium shows. Students have chance to watch interesting science demonstrations in the Minerva Theatre. Galilei is an outdoor science park where children can try and play with many interactive exhibitions. Every year Heureka organizes summer camps programme. Young children can spend a wonderful summer time camp-week in the science centre. In 2004 there were 256,231 people visited Heureka, 63,219 of which were school students which accounted for 24.7% of the visitors.

Heureka was the first non-American full member of the Association of Science-Technology Centers (ASTC). In 2005 Heureka hosted the ECSITE (European Network of Science Centers and Museums) conference. More than 600 experts from Europe and all the other continents participated in the conference.

Heureka’s future project includes the super movie theatre, a science laboratory and a big restaurant. It’s estimated that this expansion will increase the annual visitors to over 400,000.

(Heureka 2004. The Annual Report)

1.2 Children’s Laboratory

Children’s laboratory and Open laboratory located in the main exhibition hall. There are altogether six programmes developed in these two science laboratories. The bubbling chemistry, colorful chemistry, water analysis and rock examination are for young children. The DNA isolation and funny mechanics are for older children.


The most popular one is bubbling chemistry. This programme lasts for 40 minutes. The main focus is to spark children’s interest and promote observation skills development. There are altogether 24 seats in the lab. Children are required to dress in white lab coats before entering the lab. Since safety is the first consideration for chemistry study, the guide always mentions that children are not allowed to eat or drink in the lab.
Children work in pairs and take turns to do the experiments. They should keep quiet and follow the guide’s instructions step by step.

The programme is divided into three sections. Part I is about three states of matter. Children get basic knowledge about solids, liquids and gases. The activities include changing baking soda into liquid, testing baking soda and lemon juice with litmus, mixing lemon juice and baking soda together. Children can learn how to observe and predict matter changing states. They are taught to identify acid and alkaline by comparing the color difference.

Part II is “rocket launching” demonstration. The guide puts half of the effervescent tablet and two pipettes of water inside the small film container. Children are surprised to see so many bubbles and carbon dioxide gas inside the container. A few minutes later the small “rocket” blasts off successfully.

Part III is making science centre lemon juice. The guide encourages children to think about what is missing and what should add. Children learn how to add different ingredients one by one. They put water, sugar, artificial flavor, food colorings into the beaker. At last the guide puts dry ice into every pair’s lemon juice. Children are very excited when they see many bubbles and the white “clouds” coming out of the beaker.
Baby Chemists

This bubbling chemistry was developed by a chemistry teacher in the science centre. Teachers, parents and students all give high appreciation to this well-designed programme. Not only children can learn some basic chemistry concepts in the laboratory, but also they have opportunities to practice science process skills such as observing, hypothesizing, predicating, classifying, planning, measuring, etc.

1.3 Acknowledgements

The paper is dedicated to the memory of my dear grandmother for giving me delightful and carefree childhood. I would like to express deep appreciation to my mother for her love and support during the study. Many thanks should be given to Professor Lars Broman, Professor Hannu Salmi and M.Sc. Kati Tyystjärvi for their kindness and help. The last but not least I should thank 75 cute children for their cooperation and patience.

2. Formal and Informal Learning

2.1 Science Centre Pedagogy

Children receive formal education when they go to school. They can learn science knowledge from science centre, club, library, etc. Knowledge which acquired from this kind of learning settings was taken as informal learning. Compare with formal learning, informal learning is more flexible and varied. There are no formal requirements, fixed curriculum or level differences. It happens everywhere and every time. Children can always focus on learning without worrying about exams or grades. So informal learning is fun, enjoyable and playful for young kids. The vast majority of the learning which occurs within informal learning settings is based on pupil’s natural interest. The knowledge they got from the first-hand experience can make a deep and lasting impact which will be a great help for their advanced studies.

Science centre is one of the informal learning places. “It is a place where informal science education can be explored in an open learning environment without the rigours imposed by traditional school curriculum considerations” (Salmi, Hannu 2003, 461). Learning in informal settings is driven by intrinsic motivation and self-satisfaction. Visiting science centre for young children is a fantastic experience which full of laugh and excitement. In contrast with school education, learning occurs in the science centre is more naturally and freely. It absolutely stimulates a feeling of surprise, wonder and fascination.
The common aim of all science centres is to foster interest and make learning in a natural playing way. Playing is the perfect learning style for young children. Primary school students are still in concrete stage, they need to interact with concrete objects in order to understand abstract concepts. Science centre provides ample playing opportunities for children to learn by sensory interaction. They are very attentive and engrossed when they do this kind of investigative play. Sometimes kids like the experiments which full of optimal challenge and competition. If the experiments are very easy or quite difficult to handle, then young kids will soon lost interest in it. There is a popular exhibition which called traffic in Heureka. The game is about solving traffic problems. Children are divided into two groups. They should check carefully and try to solve some problems such as traffic jam, potential accident, etc. As children said “It’s interesting. It’s not very easier to carry out, so we like it.” In this case challenge becomes into powerful motivation which encourages children to learn and explore science.

Permanent and temporary exhibitions are the main focuses for a successfully organized science centre. But recently many science centres host a set of entertaining and interesting activities in order to attract more school groups. Science night in Deutsch museum, London science museum and Experimentarium in Denmark is one of the popular programmes. Children can stay in the science centre for the whole night. It’s a fresh, fascinating and unforgettable learning experience for young children.

John Dewey thought learning should be concrete and it should be as “Unscholastic” as possible (Dewey, John1916).Outdoor science centre is always seen by children as a wonderful playing and learning paradise. With idyllic natural environment as background, outdoor science centre makes use of stone, water, sun and wind to design different kinds of interactive exhibitions. In Heureka’s science park, children understand season and time by playing with sundial. They are surprised that powerful water energy can turn a water windmill. Boys and girls are curious about the wonderful music when they play with marble percussion instrument. Those interesting outdoor experiments provide plenty opportunities for young children to extend creativeness, imagination and innovation in science learning.

In the school children learn science from the textbook, but they have chances to see and touch “real things” and doing science in the science centre. For example, children get knowledge about human body in the classroom, but it’s only limited with many pictures. When they visit the science centre, young children have more opportunities to measure the length of the intestine; check the difference of the digestive system between carnivore, herbivore and omnivore; understand how heart works by observing the moveable model, etc. In the science centre children also have freedom to ask questions, make predictions and solve the problems by doing experiments themselves.

Integrated learning has been taken by many science teachers as a good teaching method for maximizing learning outcomes. They successfully “move” science classroom to the science centre. Such as study chemistry in the children’s laboratory. Learning chemistry by doing experiments makes chemistry education more interesting and full of fun.

2.2 Motivation for Learning

“Motivation: an internal state that arouses students to action, directs them to certain behaviors and assists them in maintaining that arousal and action with regard to certain behaviors important and appropriate to the learning environment” (Wiseman, Dennis G. et al., 2001).
Intrinsically motivated pupils are easier to get evolved in the learning activities and become more and more active. Learning will be more effective if it is based on children’s expectation and likeness. They feel happy and delightful during the whole learning process. There is no coercion and pressure, not for reward or special purpose. Children learn it for pleasure. “Curiosity, exploring and problem solving are key elements of the motivation” (Salmi, Hannu 1993, 109).

Extrinsically motivated students do something not exactly according to their interest and preference. Students work on tasks just because they want to please their parents and teacher, avoid punishment or get high points in the school.

Motivation is very important for science education. Self-efficacy, goal setting, task value and the learning environment are the main focuses of students’ learning motivation (Brophy 1997, Pintrich & Schunk 2002). Children of 7 years old couldn’t give precise evaluation about their own competence as older children do. They also have no special achievement motivation. Task value for young children is the tasks full of fun and they like it. Learning environment should be crucial for motivate young children thinking and learning science. Such as learning in the laboratory sparks interest in chemistry science, work in pairs or in small groups promotes science concepts understanding, teacher’s instructions facilitate cognitive development, etc. Young children at this age group still depend on teacher’s guidance and assistance. Sometimes they need teacher to give hints and comments even they are on the right track. For example, teacher helps pupils to set individual learning goals, gives positive appraisals in order to enhance children’s self-confidence, organizes science activities to nurture interest, etc.

Csikszentmihalyi talked about a kind of “flow experiences.” It means students intrinsically motivated to do something and “it felt like being carried away by a current, like being in a flow.” (Csikszentmihalyi, Mihaly 1990). When students in the flow state, they are fully involved in the learning activities. They acquire great enjoyment and freedom from what they are doing. Children have real absorption and concentration when they are playing. The effective way for motivate children is to design many programmes which focus on learning by playing.

The current research reveals that lab work makes children have a feeling of accomplishment. They are very engaged and careful when they do the experiments. Children are very pound of themselves after finishing the lab work.

“One of the key aspects of a teacher’s role is to encourage motivation for learning” (Harlen Wynne (2004). Science teaching should make use of kids’ natural interest, not only rely on external reward or praise. The outcomes of learning should be great if learning can evoke curiosity and children learn for their own sake.

3. Cognitive Development

3.1 Piagetian

Piaget divided cognitive development into four distinct stages. From birth to around 2 years old, infants are in the sensori-motor stage of thought. They learn from sensory and physical experiences.
From 2 to 7 years old, Piaget’s second stage of cognitive development is called preoperational thought. The typical characteristics in this period are egocentric, irreversibility, transductive and intuitive.

From 7 to 11 years old, the third stage of Piagetian thought is called concrete operational thought. Concrete operational thinkers can understand conservation, class inclusion, seriation and transitivity. Children’s thinking is decentered, but the realization of the mental operations is still limited with concrete materials.

From 11 to adolescence, Piaget’s highest stage of cognitive development is formal operational thought. Children are able to use deductive and inductive approaches to formulate hypotheses and solve problems. (Wadsworth, Barry J. 1996  Brewer, Jo Ann 2001, 55)

Young children’s cognitive development can’t simply fit into the same pigeonholes. That’s why some educators disagree with Piaget’s developmental stages of thought. The current study revealed that children at 7 years old still have problems for carrying out conservation and class inclusion tasks.

3.2 Vygotskian

Vygotsky believed that social and cultural factors influence children’s cognitive development. The key theory of Vygotsky was “zone of proximal development.” ZPD is “the distance between the actual developmental level as determined by independent problem solving and the level of potential developmental as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky 1978, 86). With appropriate challenges and assistance from teachers or more capable peers, children can attain more achievements which are usually beyond their existing capabilities.

Vygotsky thought the effective instruction is to give children challenging tasks which spur cognitive development. According to Vygotsky, high level cognitive competences such as metacognition, reasoning and abstract thinking originate in social interaction (Vygotsky 1978).

3.3 Problem Solving

Problem solving can be generally viewed as children’s thinking and learning (Garton, Alison 2004). When students take the problems they are studying as challengeable and interesting, their curiosity is stimulated and they are intrinsically motivated to find alternative answers.

Shulman and Keislar (1966) classified four main steps of problem solving:

1. Problem sensing: A discrepant event or an apparent incongruity stimulates the awareness of a problem.
2. Problem formulating: An attempt to define or clarify the problem is made. Solutions to the problem are anticipated.
3. Searching: Questions about the problem are raised. Information is gathered. Hypothesizes are formulated and alternative solutions are explored.
4. Problem resolving: The incongruity or disequilibrium is removed and the problem is resolved to the satisfaction of the learner.
Problem solving begins with a question. In order to help children understand some abstract chemistry concepts, teacher can raise questions which related with daily life, such as “How can we get fresh water when we travel to an isolated island? Could we drink sea water?”

The pupils will be encouraged to work out a variety of scientific solutions in order to deal with this special situation. First of all children should confirm that drink sea water which contains chemical compound sodium chloride makes people feel more thirsty. The next step is how to make sea water safe to drink. Children should be inspired to think about the water disappears in the puddle and the sugar dissolves in the water. Teacher can help students to boil the sea water first and then cool the water vapour with the beaker. The water droplets which run down the beaker can be collected in a flask. At last teacher should explain what are evaporation and condensation. If possible, children can test this distilled water, sea water, orange juice and tap water with indicator. They will soon draw the conclusion that distilled water is free of dissolved minerals, but most of water has ions in it. That’s why we can test and tell whether they are acidic or basic.

Lab work creates an appropriate environment which makes it possible for problem solving occurs. The most important thing is the problem should appeal and motivate students to get engaged in the problem-solving process. Questions which are embedded in children’s daily experiences can always grasp children’s attention and initiate further investigation for solving the problems.

### 3.4 Critical Thinking

Science learning is an active seeking and construction process. Children’s innate curiosity encourages them to learn and understand the world around them constantly. Young kids can’t act as sponge and receive knowledge passively. Critical thinking requires that children can think actively and see things from different points of view.

“Critical thinking involves grasping the deeper meaning of problem, keeping an open mind about different approaches and perspectives, and thinking reflectively rather than accepting statements and carrying out procedures without significant understanding and evaluation” (Santrock, John W. 1988, 387).

In the bubbling chemistry programme, when the teacher puts litmus into the test tube, children ask questions like “Why the color changes into red?” “Why this one changes into blue?” After mixing the lemon juice and the baking soda together, children would like to ask “Why the color changes into light grey?” “Why there are so many bubbles?” It means children can identify and compare the differences between chemicals and ask questions. This is the first stage of critical thinking. As the experiment processes, children would ask “Why the bubbles in this beaker are less than that one?” “Why we can’t touch the dry ice with our hands?” It shows that children know how to observe the phenomena from different perspectives and pose their questions. The advanced level of critical thinking is children can be metacognitive. They should have capabilities to make hypotheses, work out action plan and formulate strategies for solving problems instead of passively absorbing information and waiting for the result.

The ability of thinking critically and creatively is the prerequisite for being a future scientist. How to make young children to be good critical thinkers is a great challenge for science learning in the laboratory.
4. How Children Learn Science

4.1 Learning by Playing

Playing is always attracting for young children. Children’s play provides many opportunities for learning and understanding basic science concepts. “Play is a many splendored thing. It allows children the opportunity to be themselves, challenges them to be creative and spontaneous, gives them the tools for becoming critical thinkers and problem solvers” (Gomez, Rey A. 2005 c).

Based on Piaget’s cognitive theory, Smilansky (1968) divided play into four kinds of categories.

1. Functional play: Children get more enjoyment from functional play when they run, jump, and skip in the playground. Functional play also offers opportunities for developing cognitive competences. Children learn how to predict when they want to knock down an objective with ball. Sometimes they can understand the relationship between cause and effect when they are playing. In Heureka, there is a very popular exhibition named moon walk. Children know how to squat first, and then with the help of the spring they can easier to jump and turn around in the air like ballerinas or acrobats.

2. Construction play: Block play provides a wealth of opportunities for primary school students to develop and strengthen science concept understanding. Teacher can pose question like “How to build up a beautiful castle?” Children should think it over and try to seek for different ways to solve this problem. First of all they should match, classify and move the blocks to form into different structures. In order to finish constructing this castle, they will consider about balance, gravity, etc. All of these activities lay a good foundation for further studies in physics, architecture and engineering. In Heureka, there is one bridge building exhibition which focuses on facilitating children’s 3D reasoning and logical thinking development. Normally young children need proper instructions and guidance in order to carry out constructive play games.

3. Dramatic play: Dramatic play which combines with science learning is another type of play that really invites great imagination and creation for young children. Learning with drama enriches primary science education with endless laugh, happiness and fun.

One typical dramatic play for young kids is pretend play. This kind of make-believe helps children to extend creativity. “Child is able to take a multitude of experiences and lace them together into new ones, which represents a monument to her creativity” (Stone, S.J.1993). As children grow up, the dramatic play comes into advanced level. They can interpret and illustrate many science topics with role play. In the science fair children choose the topic “cleaning kids.” They draw the earth as like a cute kid with broom in her hands. Every child takes with broom and mop, they laugh, sing, dance and talk about “pollution, pollution, we need to find a solution.” Science studies will be more interesting and intriguing if it is combined of learning and drama together.

Role play is also very helpful for children to learn abstract science concepts. When children studying chemistry, the teacher lets them arm in arm and stand close to each other, it symbolizes the particles are tightly packed and a solid has a fixed shape and volume. Children stand separately and walk around means a liquid can change its shape to fit in any containers.
Children move quickly in all directions indicates a gas needs space and it has no fixed shape and volume (Ward, Herren. et al., 2005).

At the end of science camps programme in Heureka, young children are excited to dress in different kinds of costumes. They enjoy very much for illustrating different science topics with drama. This is a good way to impart science knowledge and spark curiosity in science learning.

4. Game with rules is a very popular form of play during the primary years. In the science centre, some children enjoy computer games in which they should follow a set of rules and formats. For example, there is an interesting computer game in the science centre which can help children to design a sport car if they can follow the instructions step by step. Game with rules supports a child’s development as he orders his world for consistency, fairness, stability and predictability (Stone, S. J .1993).

Play is crucial for early childhood education. The play-debrief –replay instructional model is based on the belief that learning by investigative play. First of all teacher should raise questions which spark interest and challenge children to make exploration. During this period, children ask questions, formulate hypotheses and make predictions. In the debriefing phase, children are encouraged to discuss and reflect what they learned from the experiments. At the end teacher poses more questions in order to stimulate children’s thinking and promote further investigation. In the replay phase, children continue with further play activities but learning and concept understanding definitely forward to an advance level (Wassermann, Selma 2000).

This teaching model can also apply to chemistry learning in the laboratory. In the beginning, the water demonstration lets children know that something running like water called liquid. The guide asks question like “Is lemon juice acid?” After children do a set of experiments, the guide asks “How can we know the lemon juice is acid?” Children will recall actively what they have done. The guide poses more questions like “How can we know baking soda is not acid?” “What do you think if we put lemon juice and baking soda together?” With the scaffolding of the guide, children understand that acid combines with alkaline can become into neutral and the color will change into light grey. By this way children are encouraged to make discovery about chemistry step by step.

Creativity and flexibility is typical of playing. During play, children will encounter with new challenges which encourage them to find new ideas and modify the old strategies. This is a good foundation for future problem-based learning. It has been observed that children playing with chemicals in the children’s lab exactly like baby chemists working in the laboratory. Children understand science concepts and practice science process skills simultaneously when they play in the science laboratory. Play provides a great opportunity for children to learn chemistry based on exploration and investigation in the laboratory.

4.2 Learning by Discovering

Discovery learning began to use in science education since the chemists H.E. Armstrong advocated heuristic approach in science class. (Harlen, Wynne 1992 Solomon, John 1980).

Jerome Bruner (1961) provided valuable theory support which was known as discovery learning. Bruner listed four reasons for using discovery approach:

1: Intellectual potency
2: Intrinsic rather than extrinsic motives
3. Learning the heuristics of discovery
4. Conservation of memory

The primary focus is to get children evolved in the active learning process and let them seek for alternative answers by themselves. As Bruner (1961) said: “the student is not a bench bound listener, but should be actively involved in the learning process.”

For learning in the laboratory, if children are told how to do it step by step, then it will limit children’s creative development. Instead of teaching “how to do this…. …. when to do that ……,” teacher should provide more opportunities for children to discover science by doing experiments. Learning is more lasting if child can solve the problems by themselves.

In Heureka’s children laboratory, the guide teaches chemistry with “guided discovery” approach. Laboratory is new to most of the children. At the beginning young children need teacher’s guidance and instructions. The teacher asks questions, inspires students to answer questions and guides them to the path of discovery.

Discovery activities provide more chances for kids to try and manipulate concrete objects and make sense of the world around them. I listen and I forget, I look and I remember, I do and I understand (Salmi, Hannu 1993, 57). This Chinese proverb describes how discovery approach works in the learning process. Discover learning which emphasizes on logical thinking and inquiry-based learning has always been viewed as the essence of science education.

5. Primary Science Education

5.1 Science Practical Work

Children spend most of their time for learning in the school. When they learn science in the classroom, the main activities for teacher are talking and explaining the science concepts, children are busy with listening and writing.

Young children are curious and action-oriented. It’s impossible for them to sit down quietly and learn the wonders of science. Practical works guide them to a brand new world which is different from the routine science classroom. The new and attracting environment in the lab makes students feel fresh and excited. Children have more freedom to learn with their senses. They can move, talk and discuss with each other when they work in pairs or in small groups. Research reveals that children are very enthusiastic for doing practical works. They enjoy and intrinsically motivated to learn science when they can do hands-on experiments in the laboratory.

As Harlen (2004, 200) said: “it allows learning by seeing and doing. It encourages discussion and debate. It is motivational.” Practical works capture students’ interests and attention. It enables children to put what they learned into practice. It can also help students to enrich knowledge, develop positive science attitudes and practice lab skills.

Hodson (1990) divided practical work into five main categories:
To teach laboratory skills;
To enhance the learning of scientific knowledge;
To give insight into scientific method, and develop expertise in using it;
To develop certain scientific attitude such as open-mindedness, objectivity and willingness to suspend judgment;
To motivate pupils by stimulate interest and enjoyment.

Chemistry learning requires that children can make observation, collect data, analyze the chemical changes and draw reasonable conclusion. So it’s impossible for studying chemistry with no practical works in the laboratory.

5.2 Learning in the Laboratory

Science belong to lab “as naturally as cooking belongs in a kitchen and gardening in a garden” (Soloman, John 1980, 13).

Traditional laboratory teaching like cook book or recipe. Teachers give exact instructions and dominate the whole learning process. Students are passive receivers. This method stifles students’ imagination and defers children’s creative thinking. The new inquiry-based learning makes it possible for students to ask questions which based on doing hands-on experiments themselves. In student-centered laboratories, the teacher acts as facilitator which challenges students with open-ended questions and encourages them to answer questions with logical thinking.

It’s very hard for young children to understand some abstract science concepts if there are no concrete learning experiences. First-hand experience is better than only learning theory in the classroom. Learning in the laboratory is a very interesting and funny experience for young children. They are very curious when they first put on the white lab coats and sit beside the bench. Children like to touch and use the lab instruments and they are eager to test by themselves. For young children, lab work actually is a fascinating opportunity to play with chemicals and see the magic reaction. So the key point of lab activities is to arouse interest and foster positive science attitudes. If lab work is boring which failed to generate a feeling of surprise or excitement, then it’s very difficult to attract children to do exploration and investigation.

In children’s chemistry laboratory, young kids are very active in trying and manipulating lab apparatus, communicate with their peers, answer questions, observe with microscope and write lab report. As children said “We make cloud. We see bacteria. Chemistry is cool. I hope I can come here everyday.” “The laboratory sets science apart from most school subjects. It gives science teaching a special character, providing many teachers and their students liveliness and fun that are hard to obtain in other ways” (White 1988, 186).

“The laboratory is certainly expected to provide for the development of motor and intellectual skills as well as problem solving abilities and affective outcomes since the major learning mode are direct experience” (Tamir, 1990b, 244). In the bubbling chemistry programme, children observe the changes in color and temperature; predict what will happen if they mix liquids together, plan what they should do in the next step, etc. So science laboratory provides an excellent opportunity for students to develop and promote science process skills.

Inquiry–based learning is very important for science education in the laboratory. The lab is one of the learning settings in which pupils can carry out the whole scientific inquiry process.
In order to activate children’s scientific thinking, the guide asks many thought provoking questions such as “What is inside the bubble?” “Is it acid?” so lab works also significantly promote creativity and divergent thinking development.

Many teachers believed that lab activity is at the very heart of chemistry education. Lab experiments allow students to learn chemistry by doing chemistry. It provides opportunities for students to learn the real chemistry rather than simply remember chemistry concepts and theories. Many hands-on experiments do help students to understand chemistry concepts and encourage them to think about those scientific theories from different points of view. When children are engrossed by a set of lab activities, they always focus their attention on the task at hand, hands-on together with minds-on greatly enhance cognitive development.

Science teacher also use demonstration in the laboratory. A good chemistry demonstration should be fascinating and interesting. Sometimes the demonstration can challenge and activate children’s science thinking which lead to further scientific investigation. As Tamir (In Woolnough, Brian E. ed., 1991, 20) said: “teaching in the laboratory requires a special approach to science, special instruction skills, special management skills and special attitudes.”

5.3 Chemistry for Kids

Chemistry is a very interesting and experimental science subject. There are many chemistry concepts which explain daily phenomena in life. We can find chemicals everywhere and it touches our daily life in different ways. Young children have superficial knowledge about chemistry. At the beginning they only enjoy playing with chemicals in the laboratory. They take it as a play experience instead of a learning process.

Teaching chemistry is as the same as teaching another science subjects. It’s essential to emphasize on pupil’s interest and encourage them to learn chemistry with full senses. Sometimes teacher can combine picture with question together in order to correct some misconceptions.

Teacher: How can we make the snowman melt slowly? Should we put clothes on them (Coats, David & Wilson Helen 2003)?

Child: Yes, they need clothes. It will keep them cold and stop melting.
Child: No. They feel warm if they have clothes on. The snowman will melt very quickly.

The snowman’s clothes can active children’s science thinking. Children wear coats in the winter in order to keep them warm. The coat serves as an insulator and helps to keep the body
temperature. For the snowman, the cloth also acts as an insulator which prevents the heat coming from outside. So the correct answer is putting clothes on the snowman.

Some interesting demonstrations can also help children to understand chemistry concepts. In the children’s laboratory, teacher boils the ice cube first, children will see the ice melts and it turns into water vapor. Then put the beaker against the vapor, it will condense into water droplets. The water can be turned back into “lollies” if it is putted into the fridge.

Some funny activities such as smell lavender, perfume, chilly and vinegar also stimulate children’s interest in chemistry. They know more about gas when they laugh and talk about the experiences.

One of the interesting demonstrations in the lab is to make volcano. Students put baking soda into a plastic bottle, pile the sand around the bottle, and leave the mouth of the bottle uncovered. At last pour the vinegar into the bottle (Hann, Judith 1999). Children can understand chemical reactions by playing with this unique “volcano eruption” experiment.

Children should learn how to make record or interpret scientific phenomena with drawing or graphics. For example, children draw sun, sea, cloud and rain in order to explain the water cycle. It’s also possible for children to present it with interesting stories.

Ask question is a very effective way to active science thinking. Teacher should help children to prove some science concepts with a set of experiments.

Teacher: Why the space suits are always white (Coats, David & Wilson Helen 2003)?

Children can find the answer in the outdoor science centre. Teacher can organize scientific activities in the sunny days. Students paint the playground with white color and black color. After a few minutes children test it with foot; they will soon find that black absorbs more heat than the white color.

These kinds of teaching methods focus on interesting and funny aspects of chemistry. It keeps chemistry as playful and enjoyable which can encourage children to do further study in chemistry.

Learning chemistry is just like learning how to dance. Only listen to the instructions and see the demonstration are not enough, the most important thing is to practice what you learned. Chemistry education based on practical works and experiments, so children learn chemistry begins from the laboratory. Chemistry is related with our daily life, so it’s better to teach children with something they like or familiar with instead of many abstract concepts. Pupils at seven years old don’t know much about chemistry, but they learned some basic science knowledge in the kindergarten. For example, put the wet cloth on the line, the water will evaporated and become into clouds. When they study chemistry in school, children can easier understand and construct chemistry concepts based on their prior knowledge.

5.4 Kitchen Chemistry

Kitchen is just like a science laboratory, cooking actually is a kind of interesting chemistry. When flour changes into delicious birthday cake, you would have to admire the magic of
Chemistry. Kitchen chemistry can spark child’s innate curiosity and it provides a lot of laugh and fun for kids learning chemistry.

Cooking offers chances for pupils to see changes when substances mix, melt, dissolve, etc. Liquids change to solids such as water becomes into ice cube, solids change to liquids as ice cream melts. Corn changes in size, shape, colour, temperature and smell as it pops. Sugar completely dissolves in coffee and forms a solution. Children can smell the odour of milk and observe how milk changes from liquid into semisolid. We can boil red cabbage to be an indicator. With this indicator we can test milk, water, orange juice, detergent, etc. Children can differentiate acid from alkaline based on careful observation of the colour changes. When bake cornbread and biscuits for children, parents can explain to children about carbon dioxide which can inflate the dough and makes the cake delicate in structure.

Children are familiar with those kinds of things in the kitchen, so it will help them to understand some abstract chemistry concepts. Learning by doing is always interesting for young children. “Taste party” is one interesting game which is suitable for science camps programme in the science centre. They can make some food under the guidance of teacher. When the food is ready, children are blindfold, and they are required to taste different food with different flavor. At the last they should describe and interpret what they feel, taste and smell.

“There are many opportunities to link the everyday chemicals in kitchens with the science that children can study practically in school” (Meadows John.2004, 84). The children’s laboratory in Heureka organized these kinds of activities in the science camps programme. Children can see how bacteria formed in yogurt. They get first-hand experience by extracting DNA from the onion. Children make use of the microscope to observe the shape of the cell and later write it in their lab reports. Those interesting science activities contribute greatly to children’s high level science thinking development.

6. Teaching Science

6.1 Inquiry – Based Learning

National Science Education Standards defines scientific inquiry as follow: Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (www.nap.edu).

Inquiry–oriented teaching begins with stimulating puzzle and astonishment. Richard Suchman (1962) developed inquiry training approach in which teacher makes use of discrepant events to motivate children learning science.

When teacher present discrepant events to students, the common reaction is: no, it’s incredible. For young children, the discrepant event is like a kind of unbelievable fact. They even suspect that teacher is making a joke. Students’ curiosity can be captured when teacher choose the topic and event which related with the daily life.

As for chemistry learning, discrepant events can be used as a challenge which will help students to create novel lab activities and acquire more information for the event. There are
many unique discrepant events which science teacher can use them in the chemistry laboratory. For example,

Teacher: Could we get the sugar back from the water? 
Children: No. It’s impossible. It disappears.

The correct answer is we can get the sugar back if the water is evaporated.

Teacher: In order to delay the freezing process, you prefer to use hot water or cold water to wash your car? 
Child: hot water (Wright, Emmett L.).

Hot water evaporates faster than cold water. It takes some of the heat and the water away. So the correct answer is cold water.

In the laboratory students can learn how to devise different tests in order to get the final conclusion

Inquiry-based learning is a student-centered instructional method. The teacher’s role is to guide the kids in finding the solutions themselves and encourage them to ask creative questions and think out innovative ideas. The student is viewed as a problem solver instead of a receiver.

The process of asking and answering questions is at the very heart of an inquiry-based laboratory. A variety of open-ended questions provide more freedom for children to present their own ideas instead of only limited with the correct answers. Children have more opportunities to think critically and creatively. In the chemistry lab the teacher can ask more open questions such as “What do you think will happen if …? “What should we do if …?” Questions by children such as “Could we test it in this way?” or “I wonder why….?” Those questions actually reflect a kind of science thinking skills development. At the same time the teacher needs to encourage children to raise their own questions and actively express their own thinking.

When children have a field trip to the science centre, science teacher can ask questions like “Why there are many bubbles in the aquarium?” This question is about oxygen. “Why arctic fish can survive in the cold water?” This question is about freezing. “Why do fireflies flash?” This is about chemical reaction with its body. Teacher’s questions and comments will encourage children to think about cause and effect. This is a good way to stimulate divergent thinking in chemistry studies.

Science is a way of thinking. Science thinking begins with a problem. Questions and problems will initiate further discovery and exploration. It encourages pupils to get involved in the inquiry-based learning and help children to extend scientific thinking.

6.2 Science Process Skills Development

Inquiry–based learning is a pedagogy which can successfully promote science process skills development. “Science process skills are those that allow students to process new information through concrete experiences” (Charlesworth, Rosalind & Lind, Karen K. 2002, 64). The key science process skills are observing, hypothesizing, predicting, investigating, interpreting,

Observing: Observation with typical cognitive components is an integrated part in primary science education. Young children should learn how to use their senses to observe the world around them. Based on the observation, children can ask questions, make predictions and carry out exploration. The observations skills can be developed in the lab by encourage children to recognize the color differences, compare the temperature changes, etc.

Observation is always a prerequisite for chemistry learning in the lab. Not only must children be able to identify the property differences of chemicals, but they also need to describe those distinctive characteristics in details. Scientific observation doesn’t mean causally browsing, children need to look at the objects carefully in order to make scientific conclusion. Teacher can ask questions such as “Could you describe what you have seen?” Nature provides a perfect setting for observation. During the field trip, teacher can ask questions like “When the grass becomes green? When the ices melt?” Children can also get more knowledge about fauna and flora when they make observation around the pond.

Hypothesizing: Formulate hypotheses is crucial for science discovery. Teacher should encourage children to make hypotheses which based on thoughtful observations. For example, “Is lemon juice acid?” “Reptiles are cold-blooded; Mammals are warm-blooded.”

Predicting: Children should have prior knowledge in order to forecast the future event and make reasonable prediction. Young children like to predict something which they are familiar with. If teaching is connected with a very interesting topic, children will eager to predict possible outcomes. The teacher can ask questions like “What do you think will happen if we mix lemon juice and baking soda together?”

Investigating: Investigation begins with a question. Question like “If the adventurer wants to drink water, how can he melt the snow quickly? Children will test with different methods in order to get the final conclusion. For example, put in the cloth, close to the fire, etc. “How can the chicken eat food with no teeth? Children will be very interested in it and make some suggestions. Teacher can tell them that chicken use part of the stomach called a gizzard to grind up food.

Interpreting: Children should lean how to recognize and explain the links between two things. For example, comparing with ice balloon and ice cube and make the conclusion that large iceberg melts slowly than small ice. Children explain about the color changes after putting the litmus in two test-tubes, etc.

Communicating: In the laboratory, teacher can encourage the students to express their ideas by doing oral presentation. With teacher’s help, some children can draw very nice concept maps about matters changing states. It’s easier for teacher to get insight into children’s thinking by looking at children’s drawing.

Comparing: Science teacher should make use of every opportunity to sharpen children’s comparing ability. For example, children know the main differences between solids, liquids and gases by comparing shell, sea water and air.

Inferring: Children make inferring based on their prior knowledge. For example, they can
infer animal based on the shape of the foot. The one with the webbed foot belongs to a bird that lives near the water; the animal with talon is a hunting bird which flies in the sky.

Classifying: Teacher should guide children to group and sort objects based on their characteristics and properties. In the aquarium, the stone is solid, water is liquid and gas is oxygen. Children are taught to classify animals into mammals, amphibian, reptile, bird, etc.

Measuring: Exactness is fundamental to science learning. In the chemistry lab, teacher should teach children how to keep measuring precisely, such as how much, how many, how often, and so on. Children should know how to measure and order volume, weight, temperature using appropriate units and measuring instruments, such as 150 ml water, 5 grams sugar, or minus 79 centigrade, etc.

7. Methods

7.1 Aim of the Study

Objective:
Children’s cognitive development
How children learn science
Young children learn chemistry in the laboratory
Teaching science

Hypotheses:
Young children learn science by playing.
Discrepant event can spark children’s interest and correct science misconceptions.
Inquiry – based learning in the laboratory promote science process skills development

7.2 Design of the Study

The current research focused on how young children learn science. Case study was young children learning chemistry in the science laboratory. There were altogether 75 children attended the pencil-paper cognitive development test, 29 pupils which coming from 4 different international schools received the pre-test, the post-test and interview. Focus groups included teachers and the guide provided valuable information and suggestions about lab education.

Children at 7 years old couldn’t write in English very well. So the pre-test, the post-test and interview were conducted by the means of asking open-ended questions and making conversations with kids. The cognitive test mainly focused on logical thinking development. The pre-test was about daily phenomena which related with chemistry. The post-test was for chemistry concepts understanding. Interview was to probe children’s thinking about lab work. Observation in the laboratory was intended to get information about outcomes of learning and teaching. Pictures taken from the laboratory illustrated how well children cooperated with
each other and how skillful for children manipulated lab apparatus such as beaker, test tube, spoon and bottle.

The current research used qualitative and quantitative evaluation methods.

7.3 Cognitive Test

The cognitive test focused on reversibility and classification.

Interviewer: Do you have sister?
Tanja: I have one old sister.
Interviewer: Does she have sister?
Tanja: I only have one sister, no more.

Interviewer: Do you have a brother?
Nicolas: I have one big brother.
Interviewer: Does he have brother?
Nicolas: I’m his brother.

The interviewer asked the same question to the students which have siblings. In general boys and girls were almost in the same level. Some answers lacked of reversibility and reasoning-based thinking.

“The ability to hold or save the original picture in the mind and reverse physical change mentally is referred to as conservation” (Lind, Karen K. 1996, 7). The following are two Piaget’s conservation tasks.

Interviewer: The two cups have the same amount of water. Is it right?
Child: Yes.
Interviewer: Now we pour water from one cup to the plate. Do the cup and the plate have the same amount of water?
Child: Yes. Because this one is tall and thin, this one is short and fat.
Child: Yes. If we measure it, we can see it’s the same.
Child: Yes. You didn’t add more water.

Children passed this volume conservation task. Some of them mentioned tallness and wideness. It means children in the concrete operational stage were able to consider multifactors at the same time.

Interviewer: Do the two cows have the same amount of grass to eat?
Child: Yes.
Interviewer: Now we separate the farmhouses to different places. Do the two cows still have the same amount of grass to feed upon?
Child: Yes. You just separate the house. There are no changes.
Child: It’s the same. Because you didn’t cut the grass
Child: I count the farmhouses. It’s the same number. It doesn’t change anything.
Child: No. There is no enough space.

4 pupils failed it. Some children were still in a transitional stage. It means they were not real conservers. They will become non-conservers if the situation or topic changed. A few of children at this age group were not able to decenter. Sometimes they gave perception-dominated answers.

According to Piaget, reversibility is the most clearly defined characteristic of intelligence (Piaget 1963b Cited in Wadsworth, Barry J. 1996, 69). The symbol of logical thinking is children can mentally reverse the action. Children should have good reversibility in order to understand some chemistry concepts. For example, the candle melts and it can’t be reversed. The chocolate melts but it can reversed even the shape will be changed.

The following three questions were for classification test.

Interviewer: What do your mum do?
Katia: She is a ballet teacher.
Interviewer: Oh, Your mother is a teacher.
Katia: No, she is not a teacher. She is a ballet teacher.

Child got confused with teacher and ballet teacher. She couldn’t reason type and subtype simultaneously.

There were altogether five choices in the second row. Children should choose one answer to match with the empty square.
This was a multiple classifications test. In order to solve this matrix problem, children need to compare with shape, size, direction and position at the same time. Students which were good at mathematics got high points for this test.

Interviewer: Are there more boys or more girls in the picture?
Child: There are more boys.
Interviewer: Are there more boys or more children in the picture?
Child: There are more boys.

Children failed this test. They were fooled by the greater number of boys in the picture. It was a kind of unidimensional thinking. Pupils always focused their attention on the salient part, they didn’t sense of boys were also children.

Classification is a very important step in children’s cognitive development. “One important skill that characterizes the concrete operational child is the ability to classify or divided things into different sets or subsets and to consider their interrelationships” (Santrock, John W 1988, 381). Classification is also one of the science process skills. In the chemistry laboratory, children should be able to recognize different kinds of chemicals and identify the different features in order to make scientific conclusion.

7.4 Pre –Test

The pre-test was conducted in the school. The whole process was tape-recorded. Children didn’t feel panic or anxious; they were more at ease when they talked with the interviewer. Young children couldn’t speak for a long time as old children did, so time was limited with 10-12 minutes for one student. In general they were very cooperative and didn’t show fatigue. Some bilingual pupils still have language problems. The interviewer needs to speak slowly, repeat or explain the questions one more time in order to let them understand exactly.

Those questions the interviewer asked were all related with daily phenomena. Child explained and interpreted it based on their daily experiences. From this we got wealth information about children’s science thinking development.

Children at 7 years old are between preoperational and concrete operational stage. During this transitional period, some of them still are intuitive thinkers. Sometimes they don’t know how to explain the reason why they choose this answer rather than that one. When they were asked “why”, the typical answer was: “I don’t know why. I just think like this.”

Interviewer: Is air gas?
Child: Air is not gas. Gas could be poison gas. Air can’t be poisonous.
Child: Air is gas. I don’t know why.

Interviewer: What’s inside the bubble?
Child: Soap or detergent
Child: Water.

Interviewer: How is cloud formed?
Child: Steam
Child: Hot air

Children always have their own beliefs about science before came to primary school. There were many misconceptions existed in young children’s mind. Those naïve ideas were not scientific, but they were based on real evidence and children’s direct experiences.

Interviewer: How to melt ice tube quickly?
Child: Put in the microwave.
Child: Put in the sauna.

Creative and critical thinking is very important for cognitive development. Sometimes Children’s ideas were very fresh, imaginative and innovative. Some ideas actually were hypotheses.

Interviewer: After swimming your bathing suit dry quickly if you stand in the sun. Why? Where does the water go?
Child: The sun dries it. The water goes into the skin.
Child: The sun heats up the water and the rain formed.

This question was about the chemistry concept evaporation. Children’s explanation always connected with their prior knowledge. They learned much knowledge about nature in the kindergarten, so it was easier for them to use the word “dry” instead of “evaporate.” They also provided many naïve answers such as: “The water just goes away.” “The water drops down on the ground.”

Interviewer: Why the grass is wet in the morning even it’s not rainy day?
Child: It’s too hot, the grass is sweating.
Child: It’s too cold in the night.

This is a normal nature phenomenon, but it is about chemistry concept condensation. This question was a bit difficult and abstract for them to give correct explanations. A few children thought it was because too cold in the night, but they didn’t know the reason. Some children thought it was morning dew, but they thought nature made water like this. They didn’t know how to explain it.

Interviewer: Could we stop air coming out of the beach ball?
Child: Yes. We can fix it with tape.
Child: We can’t stop. We can sew the cloth, even we can sew our skin, but we can’t sew the beach ball if it’s broken.
Children at this age group were easier to focus on one aspect of the question. Sometimes the answer was not to the key point. They extended the question and tried to say what ever they know about this phenomenon. This question was about the characteristic of air. Children only paid attention to the beach ball which they were more familiar with.

Interviewer: What happens when you open a bottle of Coca-Cola? Why?
Child: There are many bubbles and acids inside it. I don’t remember the name of acid.
Child: It’s carbon dioxide inside it. The pressure will come out if you shake the bottle.

The question was about carbon dioxide which they will learn in the laboratory. Only a few of them know it. Most of children mentioned bubbles in the bottle.

Interviewer: How you feel about the soap when you wash hands with it?
Child: It’s easier to go away.
Child: The hands become clean. Smell good.

Interpretation is also very important for science learning. The typical feature of alkaline which different from acid is it feels slippery. The question was to inspire them to use the correct words to describe what they see and feel about the matter in details.

Interviewer: Chemistry is related with our daily life. We use chemistry in food such as ice cream.
Child (boy): I like chemistry, but I only like ice cream chemistry.

Interviewer: Everyday we cook we are using chemistry? It’s kitchen chemistry.
Child (boy): I don’t like it. Mother does this kind of things.
Child (girl): It’s interesting.

These questions were to probe children’s thinking about chemistry. There were a bit gender differences between children’s answers. They didn’t know about chemistry. They gave positive and negative answers according to individual interests.

Did you know something about chemistry and lab?
Child: I know the word chemistry. It is about soap, water, colour and food.
Child: I have been to the lab for 2 times. Make cloud and make something better for the world.

Only a few students have basic knowledge about chemistry and lab. They got information about chemistry and lab from watching TV, visiting science centre and talking with parents or siblings. In general they know scientists working there.

Interviewer: Is chemistry interesting for you?
Child (girl): I like it. My sister is in grade 6. She said chemistry is very interesting. It’s nice to know a lot of knowledge about the world. 

According to Vygotsky, social interaction is very important for children’s cognitive development. Sometimes siblings’ opinions have a big influence on children’s thinking and learning.
Interviewer: What’s solid? Could you describe it?
Child: Something hard.
Child: Solid is slippery, such as ice.

Interviewer: What’s liquid? Could you describe it?
Child: Like water. I feel pretty wet.
Child: Juice.

Interviewer: What’s gas? Is gas and vapor the same?
Child: It can fly, not heavy. I don’t know what vapor is.
Child: The diver with a bottle on his back, inside it is gas. I don’t know what vapor is.

These questions tested children’s prior knowledge about three states of matter. A majority of children were familiar with liquids. Some students have dim understanding about solids and gases. They all have no idea about vapor. It means children have limited knowledge about science words.

Interviewer: What’s the difference between bread and water?
Child: Water is liquid, bread is not liquid. Water doesn’t taste anything, bread does.
Child: Water is wet and bread is dry.

“Logical–mathematical knowledge depends on a child’s ability to make correspondences between objects or events, that is , the ability to recognize how two objects or events are alike or different” (Forman & Hill, 1984). Some children know basic chemistry vocabulary such as liquid. But some children still have transductive thinking when they compare two different objects. For example, “water is wet, bread is soft.”

Interviewer: What happens when we put popcorn in the microwave?
Child: First it’s like seed, and then become into white, yellow and brown.
Child: You can hear the sound like “pop, pop,” and it becomes bigger and bigger.

Interviewer: What happens if we fry the egg? Does the egg change or not? What about the vegetable if we make salad with it?
Child: It’s not the oval shape anymore. It becomes flat. The vegetable doesn’t change.
Child: It will melt. You just cut the vegetable but it doesn’t change.

Children always gave brief answers. If the interviewer inspired them to speak more, then they can tell something about color, temperature, sounds, etc. The interviewer asked them more questions just wanted to encourage them to observe and learn with their senses. This is very important at the beginning of science learning. These questions were about chemical change. Children didn’t know physical change and chemical change, but they gave the correct answers based on their daily experiences. Some children have very nice communication skills. They could vividly describe the whole process together with body language. There were also misconceptions existed, such as “the egg doesn’t change if we fry it, it’s the same egg.”

What happens to the salt when we put it in the soup? Could we see it with eyes?
Child: It will melt. We can’t see it.
Child: It mixes with the water. We can see it when we close to it. It’s on the top of the soup.
This question was about salt dissolves and forms a solution. The salt broke down into small particles and then became dispersed evenly in the water. So we couldn’t see it. Children couldn’t explain it scientifically. They used the word “mix” and “melt” to describe it.

Children Did Observation Test with Picture

The bubbling chemistry programme focused on observation skills development, so the interviewer tested children’s observation skills with two pictures in the pre-test. “They enjoy the quiz book game of spotting the mistakes in two almost similar pictures” (Harlen, Wynne ed., 1985, 24). When they saw the picture, the first reaction was: Oh, I like it. They looked around and couldn’t concentrate on the questions when the interviewer asked them. Suddenly they all became quiet and engrossed when they got the picture. The interviewer told them it was just an interesting game. But they all took it very serious and tried to do it very well. Many times the interviewer said: Let’s stop now. But children didn’t hear about it.

Children were more sensitive to multi-sensory experiences, such as picture, sound and smell. In this case they were self-driven to learn or to do it. Young children were not good test – takers, actually they didn’t like to answer questions.

Pre-test results provided a vivid picture about pupils’ prior knowledge in chemistry. Children’s explanations about daily phenomena reflected how they thought about the world around them. The aim of pre-test was to awaken children’s curiosity about science with daily phenomena. They were more intrinsically motivated after they know science was a part of everyday lives. This curiosity will become into a powerful springboard for science learning in the laboratory.

7.5 Post –Test

Children spent 30 minutes in the children’s laboratory. They felt happy and excited when they did many interesting experiments. After that they did the post-test in the science centre. The test was tape recorded.

Science centre is a place for playing, so it was a bit difficult for children to concentrate on the post- test. The interviewer was like a shepherd and tried to “collect” them from different playing places to the meeting room. Young children’s attention span was short. They asked questions like “How many questions left? I want to go out and play.” “Last time you already asked many questions in the school, I don’t know why you want to do it again.” Some of them looked around, moved their body, took off socks and hided themselves under the table. The interviewer asked question like “What happens to the candle if we burn it? Where does the candle go?” One small girl answered immediately: “it goes to my tummy.” The interviewer
said: “Is it candle?” “Oh, I heard it is candy. I like candy so much.” So the interviewer should coax them and tried to attract their attention. Anyway whatever nobody went away even the door was open.

The post-test focused on basic chemistry concepts understanding. Most of the questions were about what they learned in the laboratory. Language problems still existed. Some Children from school group 2 couldn’t understand what the guide said exactly; also they didn’t understand what the interviewer said in English. In some extent it influenced the outcomes of learning.

Interviewer: What makes the small “rocket” blasting off?
Child: It's tablet and water.
Child: It’s because the bubbles.

There were also some misconceptions in the post-test. Actually it was the carbon dioxide gas made the small “rocket” flying.

Interviewer: What will happen if we put sugar into the water? Is the weight the same? Could we get the sugar back from the water?
Child: It melts. It’s the same. The sugar just disappears. We can’t get the sugar back.
Child: It mixes with the water. Maybe it’s not the same. We can’t get the sugar back.

The sugar can be recovered by evaporating the water from the solution. It’s a kind of reversibility. The problem of getting back the sugar is on a high level of cognitive development. Children need to think out a fresh idea in order to solve the problem. Some children know the weight was not the same but they thought the sugar couldn’t get it back.

Interviewer: Liquids can change into gases, true or false? Could you give an example?
Child: True. Water can change into gas.
Child: False. Liquid is a kind of form, it can’t change to something else.

Interviewer: Liquids can change into solids, true or false? Could you give an example?
Child: True. Water becomes ice.
Child: True. Frozen.

Interviewer: Solids can change into gases, true or false? Could you give an example?
Child: True. Put the dry ice into the water, it will turn into gas.
Child: False. Solid is like something hard. It can’t change into gas.

Interviewer: Solids change into liquids, true or false? Could you give an example?
Child: True. Ice changes into water in the hot sun.
Child: True. Snow man is solid. It can melt into water.

Interviewer: Gases can change into liquids, true or false? Could you give an example?
Child: True. Clouds become into rain.
Child: False. Gas like air can’t turn into liquid. It’s just air.

Those questions were about changing states of matter. Actually it was also a kind of reversibility test. Children in Finland were very familiar with ice and water. Questions like
solids change into liquids and liquids change into solids were very easier for them. Some questions were a bit abstract for them to understand. Children’s reversibility development was erratic and unsystematic.

**Interviewer:** Can a solid hold its shape, true or false? Why?

**Child:** True. The table has shape.

**Child:** False. I don’t know how to explain.

**Interviewer:** A gas can fill a container of any size and shape, true or false? Why?

**Child:** True. A lot of smoke can fill out a house.

**Child:** False. Gas can fly. It disappears quickly.

**Interviewer:** Could we compress a liquid?

**Child:** No. because the water will fall off my hand if I compress it.

**Child:** Yes, because liquid is so soft.

These three questions tested children’s knowledge about the characteristics of solids, liquids and gases. Half of the students gave correct answers. Some of them were uncertain about the questions. So they gave intuitive answers.

**Interviewer:** What’s the difference between liquids and gases?

**Child:** We can drink liquid but we can’t drink gas.

**Child:** We can see liquid but we can’t see gas.

This question was to compare the differences between liquids and gases. Children had a very clear thinking about liquids and gases after they did experiments in the laboratory.

**Interviewer:** What’s the difference between lemon juice and baking soda?

**Child:** Lemon juice is liquid, baking soda isn’t liquid.

**Child:** Lemon juice is liquid and sour, baking soda is powder. The color is different. The baking soda is white.

A few of children know the lemon juice was liquid, but some of them didn’t know the baking soda was solid. They thought baking soda was soft powder, but a solid should be very hard.

**Interviewer:** What happened to the baking soda when we put water inside the test tube? Are there any changes?

**Child:** The baking soda went down to the bottom. The baking soda got wet.

**Child:** Baking soda melted and changed into liquid.

**Interviewer:** What happened when we mixed lemon juice with baking soda together? What’s inside the bubble?

**Child:** Bubbles coming out. It was gas inside the bubble.

**Child:** Color changed. It was air inside the bubble. It was called carbon dioxide.

The questions were about what they learned in the lab. It was a kind of short-term memory test. Those activities are all related with the sensory experiences, so children can remember the phenomena very clearly.
Interviewer: What is litmus? What the color it is? How can we know lemon juice is acid?

Child: Purple, lemon juice changes into red.
Child: Purple, lemon juice is sour.

Interviewer: Is the dry ice ordinary ice?

Child: It’s very cold. It’s minus 79 centigrade. Not the same.
Child: It’s so cold. Your finger will be frozen if you touch it. Not the same.

Children only remembered some interesting things such as rocket launching, dry ice or bubbles. Only a few of them remembered science vocabularies such as acid, litmus. Some children even got confused about acid and litmus. They couldn’t remember the abstract concepts rather than concrete objects.

Interviewer: what’s chemistry in your own word?

<table>
<thead>
<tr>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>The rocket like “pa”</td>
<td>It’s about water</td>
</tr>
<tr>
<td>It’s cool</td>
<td>Make cloud</td>
</tr>
<tr>
<td>It’s great and interesting</td>
<td>It’s about air</td>
</tr>
<tr>
<td>It’s about liquid</td>
<td>Put something together</td>
</tr>
<tr>
<td>Scientist do many interesting things</td>
<td>Bubbling</td>
</tr>
<tr>
<td>It’s like something interesting</td>
<td>Change color</td>
</tr>
<tr>
<td>It’s like something good</td>
<td></td>
</tr>
<tr>
<td>Soap, water, different color, food.</td>
<td></td>
</tr>
<tr>
<td>Make cloud and make something better in the world</td>
<td></td>
</tr>
</tbody>
</table>

Boys’ answers were more interesting and full of imagination. Girls’ answers were very simple. Post-test actually was also a conversation between interviewer and children. Children did most of the talking, the interviewer just like a listener. The conversation provided us with information and evidences about children’s scientific thinking and learning in the laboratory. They offered the children’s interpretation of real learning outcomes. It also revealed how children have done the chemistry experiments, what they found interesting and what were the misconceptions.

7.6 Observation.

The whole process of bubbling chemistry programme was video taped.

The guide asked the following question at the entrance of the laboratory. Most of the students were the first time coming to the chemistry lab, so they have superficial knowledge about laboratory. A few of them which have been to the laboratory before know what they should do in the lab.
Guide: If we are chemists, what kinds of things we will do here? What should we do with chemicals? What shall we study?

<table>
<thead>
<tr>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Group 1</td>
</tr>
<tr>
<td>Animal</td>
<td>Experiment</td>
</tr>
<tr>
<td></td>
<td>Language</td>
</tr>
<tr>
<td></td>
<td>People</td>
</tr>
<tr>
<td>Group 2</td>
<td>Group 2</td>
</tr>
<tr>
<td>Do experiments</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
</tr>
<tr>
<td>I don’t remember</td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>Group 3</td>
</tr>
<tr>
<td>I don’t remember</td>
<td>Make chemicals</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 4</td>
<td>Group 4</td>
</tr>
<tr>
<td>Make science</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
</tr>
<tr>
<td>Make cloud</td>
<td></td>
</tr>
<tr>
<td>Bubbles</td>
<td></td>
</tr>
</tbody>
</table>

There were altogether 4 school groups. Students from group 2 still have language problems. The best ones were group 3 and group 4. Some kids lived in USA for one or 2 years, some of them attended English day care for a long time, so they could understand English very well.

Children were too curious and eager to do the experiments. Some of them didn’t listen to the instructions or couldn’t understand it exactly. There were a few bottles in the red box, sometimes they got confused or selected the wrong one. Only a few pupils know how to read the label first. The guide always walked around to guide and correct them.

Children took turns to do the experiment. They shared ideas and cooperated with each other very well. Works in pairs also enabled children to discuss and participate fully in the experiment.

Girls Work in Pair
Boys Work in Pair

As for fine motor skills development, most of children could manipulate pipette, bottle, spoon, beaker and test tube very skillfully. Only a few of them were not good at using pipette. In order to improve classification ability, the guide asked children to choose spoons with different sizes, select bottles with different colors. Measuring is also very important for chemistry education. The guide told them to put 150 ml water in the beaker, 10 drops litmus in the test tube, 5 drops food color in the beaker, one spoonful sugar in the plastic jar. Children were very serious and attentive for doing all of these tasks. Their facial expression and actions were really like scientists.
Lab work offered many opportunities for children to learn chemistry with their senses. They took great pleasure in doing these chemistry experiments which rich in sensory experiences.

Children at this age group were very talkative and noisy. They were quieter when the guide gave instructions. They became very active and noisy when they did by themselves. The teacher always reminded them to keep quiet. Since the children were very young, so the lab work still kept cook book like instructions. The guide adopted inquiry–based teaching method. She asked many questions which related with chemistry and the experiments. For example, “What happens?” “What do you think?” Children could understand some basic
chemistry concepts by answering open-ended questions. Those questions not only promoted science process skills development, but also enhanced lasting impression about chemistry and lab work.

Answer Questions

In general boys were more active in the lab than girls. Girls were shy and uncertain. Girls in group 3 were more open-minded than boys. The guide asked nearly 35 questions. It was about 1 minute for one question. Children answered questions very actively, but seldom asked questions. Since time was limited to 40 minutes, so the guide has no enough time to encourage them to ask questions. Children asked normal questions more than chemistry content questions. For example, “How many drops?” “Pour all the lemon juice into baking soda?” Some questions showed that children felt curious about the experiments. They asked “Why we can’t touch the ice?” “Why the ice can make sound?” “Why there are not many bubbles right now?”

School Groups and the Questions Children Answered

<table>
<thead>
<tr>
<th>School Groups</th>
<th>Closed questions</th>
<th>Open-ended questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Girls</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Girls</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Group 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Girls</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Group 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>Girls</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
School Groups and the Questions Children Asked

<table>
<thead>
<tr>
<th>Group</th>
<th>Normal</th>
<th>Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Boys</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Group2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Group3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Group 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Girls</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Children didn’t provide more creative ideas or make some prediction actively. When the guide inspired them to answer questions, they made some simple hypotheses, such as “maybe we can put the water inside the baking soda.” It means it need time to train them to be metacognitive. There was no enough time to “warm up” their thinking skills in this very short programme. The traditional recipe like instructions in some way limited the development of imagination and creation. Children still acted like passive receivers even they could ask and answer some questions.

The following questions were aim to develop children’s science process skills.

Type of the Questions the Guide asked

<table>
<thead>
<tr>
<th>Type of questions</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing</td>
<td>Any changes to the color?</td>
</tr>
<tr>
<td>Planning</td>
<td>What shall we do in the next step?</td>
</tr>
<tr>
<td>Predicting</td>
<td>What do you think about the acid?</td>
</tr>
<tr>
<td>Interpreting</td>
<td>What happened after we put them together?</td>
</tr>
<tr>
<td>Hypothesizing</td>
<td>Is baking soda not acid?</td>
</tr>
<tr>
<td>Measuring</td>
<td>How many drops?</td>
</tr>
<tr>
<td>Communicating</td>
<td>Could you explain it?</td>
</tr>
<tr>
<td>Comparing</td>
<td>Are they the same?</td>
</tr>
<tr>
<td>Investigating</td>
<td>Do you think the water can change to another form?</td>
</tr>
<tr>
<td>Classifying</td>
<td>Could you choose the bottle with lilac color on top?</td>
</tr>
<tr>
<td>Problem –posing</td>
<td>How can we change the baking soda into liquid?</td>
</tr>
</tbody>
</table>

The following were parts of the guide’s questions.
The Guide’s Questions

<table>
<thead>
<tr>
<th>Is it acid?</th>
<th>What does the acid mean?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What’s missing?</td>
<td>What do we need to add?</td>
</tr>
<tr>
<td>How does it feel?</td>
<td>What we should put in the glass?</td>
</tr>
<tr>
<td>What kinds of food taste sour?</td>
<td>What happens if we boil the water?</td>
</tr>
<tr>
<td>What does the color mean?</td>
<td>What happens if we put it in the fridge?</td>
</tr>
<tr>
<td>What happened in the test tube?</td>
<td>What do you think if we cover the test tube?</td>
</tr>
</tbody>
</table>

Demonstration which the guide did in the lab was useful to spark excitement and capture children’s interest and attention. It illustrated abstract science concepts which couldn’t be done by children in the lab experiments.

There was no gender difference for learning chemistry in the lab. Learning in the laboratory was a very enjoyable experience for all primary school students. Every child should benefit from discovering chemistry by doing experiments in the lab.

7.7 Interview

The interview was conducted in Heureka, the Finnish science centre. There were 29 pupils which coming from 4 different schools had this interview. After the pre-test and the post-test, we need to get more information about the kids’ family backgrounds, hobbies, and science attitudes in order to do cognition analization and programme evaluation.

The interviewer introduced herself and explained that she needs help to complete the task. They were all very familiar with the interviewer, so the atmosphere was very relaxed. The kids behaved just like themselves when the interviewer had a free conversation with them. But the interviewer still paid more attention to her facial expression, emphasis and intonation. Also she tried to match the English vocabularies to the level of the child’s cognitive development. Children’s responses were varied. Some children were shy, some were uncertain; some were too confident and talkative. The interviewer should consistently adjust her inquiring strategies in order to guarantee the conversation going smoothly. She always tried to keep the questions interesting if she found some of them felt a bit fatigue or were distracted.

Interviewer: What do your dad and mum do?

Child: My mum is ballet teacher, my dad helps the world.
Child: My mum studies tree, my dad works in Norkia.

Interviewer: What’s your favorite hobby?

Child: Practice piano
Child: Playing

Those two questions were to “warm up” children’s thinking. We could have a general idea about their family backgrounds.

SES (Social Economic Status) can influence children’s cognitive development. Most of the children which had interviewed came from middle class families. So there were no big
problems for SES. But well-educated parents provided more opportunities for children to develop and broaden their knowledge in science. Those children have more cognitive stimuli at home. They visited science centre frequently together with their parents, also they have chances attending science camps programme every year. So they were more knowledgeable, versatile and creative. Some children came from the families with lower socioeconomic levels only can “running, jumping, skipping.” Of course the differences of cognitive abilities not only depend on gene, it’s also important for parents’ assistance. For example, parents stay and play with child everyday and pay more attention to early childhood cognitive development.

There were not distinctive multicultural differences between those young children, but children’s performance in some extent mirrored the influences of cultures in which they grow up.

Interviewer: Are there any differences between the guide and your teacher in school? Why?
Child: Teacher teaches us how to learn, the guide teaches us how to do.
Child: There are no differences. We would have to listen and we can’t talk.

Interviewer: Did you like the guide? Why?
Child: She is funny
Child: She knows a lot of science.

These questions were to probe children’s ideas about teaching in the lab. There are some differences between teaching in the laboratory and in the classroom. As Tamir said “The teacher is undoubtedly the key factor in realizing the potential of the laboratory” (In Woolnough Brian 1991, ed., 20). Young children have no idea about teaching methods, they just compared their teacher with the guide based on their points of view. Two girls have never been to the lab before, they were very active and talkative, but the guide told them to keep quiet, so they thought the guide was the same as teacher. They have no freedom to speak in the laboratory as same as in the classroom.

We can see from children’s answers that they admired and respected their teacher. Most of them mentioned that teacher was more knowledgeable than the guide. They also like the guide, because she was cheerful, friendly and knowledgeable. The guide was indeed very helpful and patient when she guided the children to do experiments.

Interviewer: Did you learn something new today? Why?
Child: Yes, very much. We did experiments.
Child: A little bit. It’s because I already came here for 3 times.

Most of the children were the first time to come to the lab. Lab work helped them to broaden their knowledge in chemistry. They were surprised to see that chemistry was just around them, such as the cloud, bubble, lemon juice, etc.

Interviewer: Did you enjoy studying in the lab? Why?
Child: Yes. It’s fun.
Child: Yes. I like science.

Lab work was a very new and fresh experience for young children. So lab was interesting for them. They took it as a delightful playing instead of learning.
Interviewer: Did you like doing experiments with your classmates in the lab? Why? What about doing by yourself?
Child: Yes. I can talk and discuss with my classmates. I don’t want to do it alone.
Child: I prefer to do it by myself. I can always get my turn. If I do something wrong, I can try it again.

Peer studies are very important for learning. Children at this age group only focused on “don’t want to do it alone,” they didn’t mention they can learn from each other. The very funny thing was girls would like to cooperate with girls, boys preferred to stay with boys. The experiment was very interesting but not very difficult. The guide also gave very clear instructions. Children don’t need to do further exploration and investigation. That was one of the reasons a few pupils would like to do themselves instead of waiting for their turns.

Interviewer: How important is it for students asking questions in the lab? Why?
Children: Very important. If you don’t ask, then you will do something wrong
Child: Not important. The most important thing is to listen. If you listen carefully, then you don’t need to ask question.

Interviewer: Why most of your classmates didn’t ask questions in the lab? Did you ask questions?
Child: Have nothing to ask. Children know the answer. I answered questions today.
Child: They don’t know how to say. I raised my hands for one time.

Children seldom asked questions. Actually they were active but not creative. Children know it was very important to ask question. The guide should intend to develop children’s question raising ability. The most important thing is to create a lab atmosphere which is conductive to children’s intrinsic motivation and natural curiosity.

Interviewer: We will develop more new programmes in the future. Would you like to come to the lab again or not? Would you prefer to come with your parents or with your classmates?
Child: Yes. I hope I can come here everyday.
Child: Yes, with my parents.

Lab was a very interesting place for children. They enjoyed lab work, so they all preferred to come again in the future.

The aim of interview was to encourage pupils to express their thinking in their own words. The best way to assess the learning outcomes was through talking with children. Children’s talking revealed their ideas and attitudes about this programme. They evaluated this programme with their own standards. The conversation provided more detailed information about what they felt fascinating, what they were interested in chemistry.

7.8 Focus Groups

Focus groups encourage group interaction and in-depth discussion, revealing feelings, attitudes and perceptions (Krueger, 1988). Group members “who are unfamiliar with one another, but share certain characteristics” (Borun Minda, 1998).

Focus groups included teachers and the guide provided comments and suggestions about
science learning in the laboratory.

Teacher from Holland

The bubbling chemistry is a very nice programme for young kids. Due to the limitation for equipments and space, there is no lab in the school. So learning in the lab is a great experience for kids. They are really excited about it.

The guide plays an important role in the laboratory. She asked questions and encouraged pupils to get involved. The guide did everything in a natural way. This short programme went extremely well and children were really eager to see what would happen in the next step. Quite often people are not used to teach kids and get them curious about something. They use some difficult words which are not suitable for kids to understand.

There is no gender difference in the lab. It’s quite possible for both boys and girls at this age to be interested in science, math, football etc. It depends a lot on the nature of the child and his or her environment.

The bubbling chemistry fits in with the curriculum development. There are always children who want to listen to the instructions and there are others who want to do experiments and explore by themselves.

Kitchen chemistry is a very good way to motivate the children. Kids always like to try something new. Kitchen chemistry can also help to improve measuring ability.

Group work or work in pairs is generally important. Children can talk about the process and follow what is happening together. It’s a good way to learn how to listen, respect and cooperate with each other.

Learning by understanding is important. Listening and reading followed by an activity are good tools for better understanding. The children talked about their lab experiences with their buddies in class 6B in the following days. They told them what they had done and shared their knowledge with older children.

I think the lab is a wonderful opportunity for children to get in touch with science.

At this age the kids are eager learners. Quite many students have several interests and ask a lot of questions. Others feel more at ease just to listen to the facts. It’s very individually. They are talking about all kinds of information and are open-minded for new tasks. They always have their own opinions.

Teacher from Finland

The bubbling chemistry is an interesting way to learn some physical laws by using different senses. An advantage for this programme is that the kids may start to become interested in learning more about the environment around them. I don’t see any disadvantage.

The bubbling chemistry fits in with the curriculum development. One of the learning goals for primary school students is to learn scientific knowledge by using different senses. I think experience is very important for young children.

The way talking with young kids need to include more basic and describing words. Children
at this age cannot think abstractly. And new scientific words are impossible to realize. The more they have opportunities to think with the vocabularies they already have, the more they really learn.

The informal learning situation will encourage kids to ask more questions. The pupils learn something new today. I’m sure they would like to come back to do more science experiments in the lab. There is no gender difference for learning in the lab.

Kitchen chemistry is very good because it will offer opportunities to do some experiences again at home kitchen. By this way we can heighten the kids’ motivation and stimulate the pupils’ interests.

Teacher from Finland

Bubbling chemistry was very interesting for children, they enjoyed participating in the activities.

The disadvantage is some terms were difficult to understand for young children.

Discrepant event in the lab absolutely is a good way to spark pupil’s curiosity.

The kids didn’t ask questions in the lab. They obviously didn’t understand all the questions. Some children may be shy when they are with different surroundings and adults.

The guide plays a crucial role for encouraging the pupils to get involved in active learning.

I don’t think there are gender differences for learning in the lab.

Bubbling chemistry fits in with the curriculum development in the school. Chemistry learning will come later in the school curriculum.

Yes. Kitchen chemistry can heighten the kid’s motivation and stimulate the pupil’s interest.

As for cognitive development, my opinion is to learn little by little. Learning and developing in certain area is fun.

Group work or peer study is very important for studying in the lab. By this way children can learn from each other.

Working in the lab has to be organized due to the safety reasons. Children can not be creative if they have given strict instructions and guidance.

The pupils at this age group to certain extent have their own scientific ideas before studying in the lab.

At this age they are willing to follow the adult and working in the lab is new for them. I ’m sure they learned a lot in the laboratory.

I think studying in the lab can improve pupils’ observation and predication abilities greatly.
Science is always a subject that many children find interesting. It is a so broad subject and there are many different ways to learn science topics.

They might not be able to remember all the chemical concepts from one time trying but can probably recall what they experienced when they do similar tasks again.

Learning by science playing is a very good and challenging way for teaching primary science.

The guide from Finland

I’m not native English speaker; some kids also have language problems even they study in the international schools.

I can make it more interesting if it’s taught in Finnish. It’s easier for me to grasp kid’s attention and arrange demonstration and instructions. I can use analogy which should be easier for kids to understand some difficult chemistry concepts.

Young kids seldom ask questions. The kids come to a very new environment and face a new guide. They still feel a bit nervous. This programme only lasts for 30 minutes, I have no time to warm them up and let them feel relaxed.

As for teaching style, I prefer to use inquiry-based teaching method. I asked open-ended questions and closed questions from easy ones to difficult ones. Some kids are very shy, so I think it’s better to let them listen instead of push them to answer questions. Otherwise it will distract their attention. Normally I just encourage them to get involved in the activities.

Kids are curious about the laboratory, so they are eager to do it without listening to the instruction carefully; sometimes they get confused with those bottles. I think it’s very important to give them instructions exactly.

Most of the kids can remember more practical things. The aim of this programme is to spark interest for chemistry learning. Kids don’t need to know many chemical vocabularies. It’s too abstract for them to understand.

Many kids do have prior knowledge about lab. Some children’s parents work in the lab. Some of them visited the children’s laboratory for 2 or 3 times. For example, they know people can mix something together and produce new substances in the lab.

Learning by doing is very interesting for them, but sometimes an interesting demonstration also can attract kids’ attention, such as this rocket launching demonstration.

Working in pairs can make them cooperate with each other. I think discrepant events are very effective for teaching in the lab. As for fine motor skills development, it really depends on pupils. Some young kids can use the spoon and pipette very well.

In general focus group participants gave positive appraisals to this programme. They thought children learned a lot from doing experiments in the laboratory.
8. Results

Cognitive test

![Figure 1: Cognitive Scores](image)

The cognitive test included 12 matrix problems altogether 12 points. There were 4 school groups altogether 75 students attended the cognitive test.

There was no one in group 2 which got full points, but students in this group all got high points compared with another 3 groups. Students’ cognitive development in this group was almost in the same level. There were more students in group 3 and group 4 which got high points. Six students in group 3 got full points; six students in group 4 got 11 points. In general there were more students in group 1 got low points compared with other three groups.

![Figure 2: Gender Difference for Cognitive Development](image)

The average scores for boys were 7.23; girls were 7.31. The average cognitive scores (n=75) for girls were slightly higher than boys. P value=0.927 (P >0.05), so there was no statistic significance between boys and girls.
Pre-test

![Bar chart showing the percentage of students from four school groups (n=29) who found chemistry interesting.]

**Figure 3: Chemistry is Interesting**

The interviewer asked the pupils if chemistry was interesting for them. The typical answers from four school groups (n=29) were as following:

- Very interesting: 12.50% students from group 2
- Interesting: 50% students from group 4
- Somewhat interesting: 85.71% students from group 1
- Little interesting: 25% students from group 3
- Not interesting: 12.50% students from group 2

Children have superficial knowledge about chemistry before they came to the laboratory. So a majority of children thought chemistry was somewhat interesting during the pre-test. They all thought chemistry was very interesting and full of fun after came back from the laboratory. It was because they touched the concrete materials and did experiments in the lab.

![Line graph showing the average scores of boys and girls.

**Figure 4: Gender Difference for Learning Chemistry**
The average scores (n=29) for boys were slightly higher than girls. Boys (15) were 3.47; girls (14) were 2.86. P value =0.064 (P >0.05), so there was no statistical significance between boys and girls.

**Figure 5: Knowledge in Chemistry**

There were 7 students in group 1, 8 students in groups 2, 8 students in groups 3 and 6 students in group 4. 100% students from group 2 have no knowledge about chemistry. 50% students from group 4 have basic knowledge about chemistry. It was very difficult for children at 7 years old to define chemistry. They have a vague concept understanding for chemistry. Some children know the word “chemistry”; some of them saw chemists working in the laboratory from film and TV.

**Figure 6: Gender Difference for Chemistry Knowledge**

13.33% boys and 28.57% girls (n=29) have knowledge about chemistry. P value =0.335 (p>0.05), there was no statistically significant difference between boys (15) and girls (14).
There were altogether 29 students. 100% Students from group 1 have no idea about laboratory. Students in this school have never been to the children’s laboratory before. 50% Children from group 4 know about laboratory. Some pupils from group 2, group 3 and group 4 went to the children’s laboratory at least for 1 or 2 times. Two students’ parents in group 2 worked in the laboratory. In general children have more knowledge about lab than chemistry. Most of Children didn’t see any connections between lab and chemistry learning. They thought lab was just lab; there is no connection with chemistry.

20% boys and 35.71% girls (n=29) have knowledge about laboratory. P value=0.362(P>0.05), there was no statistic significance between boys (15) and girls (14).
There were 8 differences in two pictures altogether 8 points. Six students (n=29) got full points. No one got 1 or 2 points. In general there were more students which got 6 and 7 points.

There were more girls which got high points than boys. The averages scores (n=29) for boys were 6; girls were 6.1. P value=0.813(p >0.05). There was no statistic significance between boys (15) and girls (14).

**Post-test**
There were altogether 29 students. One correct answer was one point; one wrong answer was 0 point. The full scores were 5 points for 5 questions.

80% correct answers were for solids change into liquids, 10% for gases change into liquids. Children were very familiar with ice and water, so they gave more examples about solids change into liquids and liquids change into solids. Only a few students know about liquids change into gases and solids change into gases, even in the laboratory the guide mentioned more about water changing into water vapor and dry ice changing into carbon dioxide gas. It was also very difficult for them to image that gases can change into liquids.

The average scores (n=29) for boys were slight higher than girls. Boys were 2.26; girls were 2.14. $P$ value = 0.81($P >0.05$), so there was no statistic significance between boys (15) and girls (14).
25 (n= 29) students know dry ice was very cold. Only 9 students remembered testing lemon juice with litmus. Young children were more impressed with multi-sensory experiences. There were more children know dry ice was not allowed to touch with hands, lemon juice tasted very sour, and the gas made the small “rocket” launching. These were all related with their senses. Only a few of students know how to test acid with litmus, even the guide mentioned many times in the laboratory.

**Figure 13: Learning in the Laboratory**

**Figure 14: Total Average Scores between Pre-Test and Post-Test**

Questions for the pre-test:
1. What’s solid? Give one example?
2. What’s liquid? Give one example?
3. What’s gas? Give one example?
4. After swimming, your wet bathing suit and skin dry quickly when you stand in the sun. Where does the water go?
5. Why grass is wet in the morning even it’s not rainy day?
6. What happens when we put salt into the soup?

Questions for the post-test:

1. Can a solid hold its shape?
2. Could we compress a liquid?
3. Can a gas fill containers of any shape?
4. Liquids change into gases, true or false? Give one example.
5. Gases change into liquids, true or false? Give one example.
6. What happens if we put sugar into the water?

Questions 1-3 were about the characteristics of solids, liquids and gases. Questions 4-6 were about chemistry concepts evaporation, condensation and dissolve.

One correct answer was for one point. One wrong answer was for 0 point. The average scores (n=29) for pre-test were 1.55; post-test were 2.12. P value = 0.04(p<0.05). There was significant difference between the pre-test and the post-test. Children were motivated and they got more knowledge about three states of matter in the post-test than in the pre-test.

![Figure15: Gender Difference for Pre-Test and Post-Test Scores](image)

In the pre-test, the average scores for boys (15) were 1.73; girls (14) were 1.35.

In the post-test, the average scores for boys (15) were 1.93; girls (14) were 2.28.

Mean difference between pre-test and post-test for boys (15) were 0.02; girls (14) were 0.92.

Girls were slight higher than boys. P value= 0.17(p>0.05). There was no statistic significance between boys and girls. It means there was no big difference between boys and girls for the level of improvement.
Interview

![Graph showing the number of students' responses to learning something new in the lab.](image)

**Figure 16: Learning Something New in the Lab**

4 girls and 5 boys thought they learned very much in the lab. 1 boy and one girl thought they learned a little. Most of students thought they learned much or some. Some children went to the laboratory 2 or 3 times already. Actually they were very familiar with it, so they said they just learned little or some. The average scores (n=29) for boys were 3.93; girls were 3.92. P value =0.989 (P >0.05). There was no statistic significance between boys (15) and girls (14).

![Graph showing the number of students' attitudes for working in pairs.](image)

**Figure 17: Attitude for Working in Pairs**

Boys and girls almost have the same ideas. Most of the students like to cooperate with their classmates. The average scores (n=29) for boys were 4.60; girls were 4.64, P value =0.857 (P >0.05). There was no statistic significance between boys (15) and girls (14).
7 girls and 4 boys thought asking question were very important. 1 boy thought it was not needed. The average score (n=29) for boys were 3.40; girls were 4.07. P value =0.161 (P >0.05). It means there was no statistic significance between boys (15) and girls (14).

9. Reliability and Validity

“Reliability is a measure of how consistent a research method is. A reliable method measures the same thing, usually in the same way, each time it is used” (Diamond, Judy 1999, 77).

There were four school groups attended the pre-test. Children from group 2 couldn’t express their own ideas exactly due to the language problems.

The post-test and interview were conducted in the science centre. Children’s attentions were distracted by many interesting exhibitions, so they couldn’t focus on the questions.

The interviewer had interview with two pupils at the same time due to the time limitation. Sometimes one child said “me to” or the “the same” instead of expressed their own ideas. Some kids said: “maybe yes, maybe not.”

Time was limited. Interviewer has no enough time to inspire children to answer those questions. Sometimes they could give correct answers if they got more hints or suggestions.

Mathematics is fundamental for science learning. Some kids were not very good at mathematics; their teacher also said they were normal in reasoning and logical thinking, but they have rich knowledge about science. So they gave more correct answers in the test, especially for girls. Some kids even got scholarship in mathematics in school, but they didn’t get high points in cognitive test, also they performed very normal in the pre-test and the post-test, it was typical for boys. It means there were still minor differences between true cognitive development in school and cognitive test in the science centre.

“It’s important to know the means of assessment you have developed is accurate and appropriate. This is what is usually referred to as validity in research” (Diamond, Judy1999, 75).
It was very effective for conducing pre-test and post-test by making conversations with young kids. Children at this age group speak better than writing. What they said reflect their true feeling and attitudes.

There were all together 12 matrix problems used for cognitive test. In general every child can finish one for one minute. The test was appropriate to children’s logico-mathematical knowledge development.

The observation test with two pictures grasped children’s attention and stimulated their thinking greatly.

The interviewer took pictures when children did experiments in the laboratory. From children’s facial expression and body language we can make conclusion like this: Children like lab work very much.

The information which got from the observation was true. Children at this age group never mind if someone made observation in the lab. They did whatever they wanted to do. Children performed very naturally and freely.

10. Discussion

There is a strong connection between play and cognitive development. Play has a crucial role in developing abstract thought in young children and continues to afford children of all ages the opportunity to use divergent thinking (Pepler, 1982). Play is an excellent learning and teaching strategy. When children learn chemistry in the laboratory, they take it as a wonderful playing experience. A feeling of playfulness accompanies the whole learning process in the lab. They indulged themselves in those interesting experiments and forget they are learning something in the laboratory.

One of important science attitudes is curiosity; science teacher can stimulate children’s curiosity by presenting discrepant events. The bubbling chemistry programme didn’t mention discrepant event. When children put the sugar into the water, it’s possible for the guide asks question like “Could we get the sugar back? Where does the sugar go?” At the beginning they would declare “no, I don’t think so.” If the guide says: “yes, we can do it.” It would be a big surprise for children. Discrepant events create a kind of cognitive dissonance. Children’s innate curiosity is “hooked”; pupils have a strong motivation to find the answer. Children will be encouraged to observe, predict and infer until getting the final solution. Actually discrepant events open a window for children to make further investigation and gain in depth understanding to the topic.

Scientific inquiry includes “opportunities for students to ask questions, plan and conduct investigations, use appropriate tools and techniques to gather data, think critically and logically to develop explanations based on what they have observed, construct and analyze alternative explanations, and communicate scientific arguments”(National Science Resources Center 1997, 69). According to Alan Colburn, inquiry is “the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities.” He divided inquiry –based instruction into structured inquiry, guided inquiry, open inquiry and learning cycle (An inquiry premier www.nsta.org/main/news/pdf). The bubbling chemistry programme adopted structured inquiry. Actually there was no big problem solving activity. Some questions presented a few simple problems. For example, “How can we compare lemon
juice with baking soda powder?” Children formulated some simple hypotheses but seldom asked questions. Raising problem is typical for inquiry-based learning. Young children were given step by step directions. They did everything according to this “recipe,” so the imagination and creation couldn’t be developed. This was one reason children didn’t ask question, just like they said: “We have nothing to ask. Children know the answer.” Children will be more actively to pose their own questions, make hypotheses and interpret data if they are really involved in the decision making process.

Asking question plays an important role in inquiry-based learning. Teacher shouldn’t only limited with asking normal questions, they should know how to ask scientific questions in order to get more children involved in the science learning process. Good open-ended questions can encourage children to think actively which lead to effective science exploration. Closed questions sometimes make pupils nervous and panic. Some children would like to give it up due to afraid of providing wrong answers. “The most productive kinds from the point of view of learning science are those that enable children to realize that they can raise questions and answer them for themselves” (Harlen 2004). “Learning to ask good questions is an essential ingredient for science” (Smith and Peacock 1995). Help children to get involved and ask questions is very important for science teaching. Children can raise questions means they are interested in this topic. At least they understand part of the topic and they would like to know more about the science phenomena.

Science teaching should aim to spark children’s interests, challenge children’s potential abilities in a scientific way. Learning is more effective if it is based on interactivity. Children need something new to try, touch and manipulate.

Teaching chemistry with toys is a discovery based approach developed by national science foundation-funded teacher training programmes at Miami University of Ohio (National Science Foundation 1997). Learning science with toys enable children to become fascinated with science. Many science activities based on toy playing do engage children in creative, constructive and investigative learning process. It can also help to accelerate children’s cognitive development if the toys are unique and educational. Their innate curiosity in science together with their eager to play with toys is the great motivation for learning. For example, teaching chemistry with bubbles, ice balloon and eastern egg, etc.

Children’s science thinking which based on daily experience is usually intuitive and perceptual-dominated. Those misconceptions will be a barrier for children to accept new science concepts. Teacher should try to find useful teaching approaches in order to help children to correct it.

The following are two examples of misconception in chemistry.

Interviewer: What’s inside the bubble?
Child: Nothing.

Interviewer: What’s the cloud formed?
Child: It’s a kind of smoke but not like smoke.

The national curriculum (DfEE) states primary school students should be able to “use simple scientific language to communicate ideas and to name and describe living things, materials, phenomena and processes.” Children at 7 years old have superficial knowledge about scientific words. They know the words such as “melt, freeze, mix,” but they have no ideas
about evaporation, dissolve, and water vapor. The guide should intend to teach children some basic words in chemistry. When she asked children to put sugar into the water, actually this was a dissolve process, but most of children only know the word “mixing.” It was also difficult for children to remember some scientific vocabularies. For example, the guide told the children: this is acid, this is not acid. During the post-test, children didn’t know what’s acid. Instead of said “this is not acid,” the guide should tell the children “this is alkaline.” Maybe children can’t remember at this moment, but it’s better to teach the correct chemical vocabulary from the beginning. How to make children interpret scientific phenomena with basic science words is one of the main considerations for science education.

Science learning should be more effective if it is connected with daily life successfully. Science teaching is supposed to use everyday things so that children can see the connections between science at school and their own lives. During the devastating 2004 Tsunami in Asian, a 7 years old British girl saved more than one hundred people in a small island in Thailand. She was very interest in learning science. When she saw a white line were coming near to the beach. She told her parents the potential danger, so they asked many tourists to move to safety places quickly. A few minutes later the sea water engulfed the beach. The small girl was later named by people as “beach angel” (www.wenxuecity.com). Science knowledge is powerful even for a young kid. Not only can you become more knowledgeable but also make life meaningful.

Piaget believed children at preoperational stage think intuitively and transductively. In the pre-test, some children know the answer, but they couldn’t explain it with logical thinking. So they always said: “I don’t know why.” In the post–test, children showed transductive thinking. Children’s thinking jumped from one subject and event to another subject and event. The typical answer was: “Lemon juice is wet, baking soda is not acid.”

Piaget’s cognitive development theory exerts significant influences on primary science education. Some cognitive competences which Piaget stated in the stage development fit in exactly with the goals of science education. Piaget thought concrete stage children can mentally reverse action. Some children demonstrated reversibility when they answered the questions in the post-test. They have a very clear thinking about matter changing states. For example, they know physical change can be reversed. Such as water changes into ice, ice changes into water, etc. They also know chemical change can’t be reversed such as the egg will be changed if we fry it.

According to Piaget (1970), knowledge can be divided into physical knowledge, logico-mathematical knowledge and social knowledge. Logico-mathematics knowledge is very important for primary science learning. In general students which good at mathematics are all very good critical thinkers and problem solvers.

Piaget (1962) thought there are two functions for playing, one is for joy, and one is for learning. The lab works do provide enjoyment for young children when they mix chemicals and see the magic reaction. Learning in the lab also offers chances for young kids to learn chemistry concepts and practice manipulative skills.

Vygosky (1978) thought teacher and peers play an important role for encourage children getting evolved in the study. Children worked in pairs when they did experiments in the lab. They discussed and helped each other very well. The guide also gave them good instructions when they did experiments.
Informal learning is “activities that occur outside the school setting, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation as part of a credited school experience” (Crane, V 1994). Children begin to study chemistry at 11 years old; lab work is a part of formal learning for teenagers. Lab work should connect with their routine study even learning occurs out of the school environment. Children are always busy with finishing their lab reports in order to pass the exams. It’s not a delightful experience anymore. That’s why some chemistry teachers complained that teenagers are not very interested in chemistry learning.

In contrast with teenagers, young children at 7 years old have no chemistry class in the school, so learning in the laboratory is still a kind of informal learning for them. They are more easily motivated in doing experiments than learning in the classroom. The prior knowledge in the lab will lay a good foundation for advanced chemistry studies.

Learning in the lab should start from safety. The correct operation is very important in the chemistry lab. When mixed baking soda with water, the guide asked the child to put one finger on the top of the test tube and shake it. Actually it was a wrong operation. It’s supposed to tilt the test tube carefully and make the chemicals mixing with each other slowly. Everything in the lab must be as accurate as possible, especially for teaching young kids.

The main purpose of this programme was to foster children’s interests in chemistry study. They only felt interesting, but couldn’t remember something in details. Time was limited to 30 minutes, children were required to listen and follow the instructions, and they really have no chance to do investigation in the lab. If they have opportunity to do investigation by themselves, the learning outcomes should be different.

Children worked in pairs in the lab. A few students thought they were only allowed to do part of the experiment, so they would like to do it by themselves. It’s possible to work in small groups and focus on one topic. By this way children have more freedom to discuss with each other and every one can have their own task.

Bubbling chemistry should guide pupils to make records. For maximum learning benefits, lab activities must be minds on as well as hands on. Such hands on and mind on approach gives students the opportunity to increase their problem solving and critical thinking skills.

After teaching in the lab, the teacher should cooperate with the guide to give students some home assignments, such as make a new red cabbage indicator to test detergent. It can help to enrich chemistry knowledge and promote chemistry learning.

Boys and girls were very interested in doing experiments in the laboratory. There was no big gender difference between boys and girls learning chemistry in the lab.
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National Science Education Standards


Appendix

A.1 Cognitive Test
A.2 Pre-Test

What's inside the balloon? Why?

Air. It's flying.
Air. We blow air inside it.
Air. The air will come out when it’s broken.
Air. It goes high up and doesn’t go down
Air. Sometimes could be air. Sometimes could be gas.

Is air gas? What’s inside the bubble?

Air is gas. It’s gas inside the bubble.
Air is not gas. There are soap and shampoo inside the bubble.
Air is not gas. There is nothing inside the bubble. Maybe a little bit soap or water.
Air is not gas. Gas could be poison gas. Air can’t be poisonous. Water.

How do you feel about air? Could we stop air coming out of the beach ball?

Feel pretty cold when you touch air. No. We can’t stop it.
Feel nothing. I can stop it, just put tape on it.
I can feel it in the windy day. No. It’s so fast we can’t do it quickly.
Yes. You can put your hands on the hole.
It feels like nothing. No. We can’t stop it. I don’t know why.
I feel flying like a bird when I stand on the top of a hill. We can’t stop it.
In winter it is a bit cold, in summer is not so cold. We can’t stop it.
It’s fresh. No. We can’t fix it if it’s broken.
We can sew our clothes, even we can sew our skin, but we can’t sew the ball if it’s broken.

What happens when you open a bottle of coca cola? Why?

It will come out if we shake it. It’s carbon dioxide.
There are acids inside it. I don’t remember the name of acid.
The pressure will come out if you shake too much.
Bubbles and air will come out. You must do it quickly and close it.
It will well out if you shake. It’s gas.
It starts to fizz. It will drain out of the bottle.
It’s just likes wine. It will come out if you shake it.
Bubbles fall down to the floor if you shake too much.
It will come out like bubbles. It’s because there is gas inside it.
Bubbles have no space, so they will come out.

What happens to the salt when we put it into the soup? Can you see it with your eye?

It just goes away.
It goes into the soup. It mixes with the water. It’s invisible.
Disappear. It’s so small, we can’t see it.
It melts into the water.
The soup gets very salty. I can see it on the top before I mix it.
Taste different. It will go down to the soup.

What happens to the popcorn when we put it in the microwave?

Pop. The seed will become into popcorn.
Pop. Like a circle like brown.
It starts to pop, smell good.
It will go up and down. Smell better. It will become half white and half yellow. Start to pop with sound. It’s hot when you touch it. At the beginning it likes a small seed, and then it changes into white, brown and yellow. You can hear the sound like “pop, pop,” and it becomes bigger and bigger.

**What happens to the egg when we fry it? Any changes? Are there any changes to the vegetable after we make salad?**

It melts. Egg will be changed if you cook. No changes for vegetable. They are the same as they were. The egg is the same egg. There are no changes. It becomes bigger. It will be more hot and soft. It will be flat and a bit harder. The vegetable just get into small pieces. No changes for vegetable. First it’s soft and then it will become a bit hard. Put it in the pan, it will become flat, a white circle and another yellow circle. The vegetable is the same. It will get flat and soft. No changes for the vegetables. It’s not like oval shape any more. It just melts. You just cut the vegetable but it doesn’t change.

**What happens to the snow man if the sun shines, why?**

Melt Snow is very cold and sun is hot. It will get into water. Melt. The sun is hotter than snow. The ray of the sun is too hot. Melt. Snow doesn’t like sun. Snowman made of snow. The warm melts the cold. It will melt. The snow is cold. The sun is warm.

**After swimming, your wet bathing suit and skin dry quickly when you stand in the sun. Why? Where does the water go?**

Sun is hot, water is wet. The water will go into the ground. Sun is hot and water evaporated. Water goes in the air. Sun is hot and dries the water. The water drops down on the ground. Sun dries it. The water is inside the skin. Sun is very hot. The same thing as you dries your hair. The sun is warm, and then the wet go out of you. Sun is drying. Sun takes the water away. Water is not as hot as sun. The sun heats up the water and the rain formed. It formed the clouds. It is because clouds made of raindrops. Sun is hot. The water dries off into the sun. Sun is hot, water is not hot. It just goes away. Sun is very warm. Like drink water. Water goes through warm. Sun is warm. You don’t need to dry by yourself, just sitting in the sun. You will get sunburn if you stand in the sun for a long time. The sun dries the skin because the skin is wet. If the tree is wet, the wind blows, the water will drop on you.

**What happens to the lake in the winter time? What’s the colour of the ice? Is it the same as snow?**

It’s frozen. It’s so cold. Snow is soft and the ice is like rock and hard.
Frozen. The ice is transparent. Ice is hard, snow is soft.
Frozen. It’s cold. Ice is blue.
Frozen. Ice is white and a bit blue, it’s close to snow.
We can see through the ice, it’s clear. Snow is soft.
Ice is blue. Ice is slippery and hard; snow is soft, not slippery. Snow melts quicker than ice.
It will come to the ice. Snow is very white, ice is not so white.
It is very cold and it becomes into ice. It’s white or silver. Ice is hard and snow is soft.
Ice is easier to get broken. Snow is soft.

**How is the cloud formed?**

Hot air.
They like cotton.
Fire and smoke go up and cloud formed.
Gas goes up and cloud formed
Steam.
Water goes up to the sky and come to a cloud.
Inside it is water. The water comes out of it when it starts to rain.
Raindrops in the puddle will go up and become clouds when the sun shines
It’s made of this kind of smoke, but not smoke.
Water
Water smoke. The water dries out and it comes into smoke.
It likes cotton candy.

**Sometimes the grass is wet in the morning even it isn’t rainy day, why?**

In the summer, the snow already melted into the water. Then the water goes into the grass.
It’s cold so the ice will appear.
Grass grow need water. People water the grass.
It’s morning dew. Nature makes water but I don’t know why.
It’s cold. Gas turns into the water.
It rained in the night; the sun didn’t come out in the morning. That’s why it’s wet.
Sometimes it’s cold there, so it will become wet. If it’s snowing, the grass is also wet.
It’s dew. It’s very cold in the night.

**How can we melt an ice cube quickly?**

Put fire close it.
Some hot place
Put it in the sun
Put it in hot water
Put on the beach
Put in the microwave
Rub it in your hand.
Put in the oven
Put in the sauna.

**What’s baking soda? What’s it used for?**

Put it in the cake
It’s for cooking.
It’s like flour. It’s for baking bread and cake
Like potato powder.
It’s a powder for cooking pancake.

**Are there any changes if we pour milk into the hot coffee?**

Yes, it comes into another colour. Taste different.
There are more liquids. The coffee will go up.
Get cold. The colour will change to light brown.
Coffee will get better. Taste better.

**How you feel about the soap when you wash hands with it? What about detergent? Is it the same as soap?**

It’s slippery. We wash dishes with detergent, and we wash our hands with soap.
It’s fun. There are bubbles inside it. I like the bubble. I put it in my finger it will never burn out. It will burn out if I put on water.
It’s easier to run away. Hand soaps like a block, the detergent like liquid.
It’s wet. Soap is like slippery, the detergent is not slippery.
It’s slippery. Detergent is like water. It’s not the same.
Dirty hands become clean. We wash plate and spoon with this. It’s different from soap. We use soap with our hands.
My hands smell good. It’s slippery. Detergent is liquid.
Your hands are clean and there are bubbles.
Your hands come into wet. The soap is hard. The detergent has different colours.
There are different kinds of soaps. We can’t use detergent to wash everything.

**What’s the difference between bread and water?**

We eat bread and drink water.
Water is wet, bread isn’t wet.
Water is liquid, bread is not liquid. Water doesn’t taste anything, bread does.
The water is wet and bread is dry.
Water is wet and bread is soft.
We can drink water, we can’t drink bread
Water feels light, bread feel a bit heavier.
Bread is more like tough and hard.
Water is so running, and bread is quite soft.
Bread is food, water is drink.
Bread is harder than water.
You can’t cut water, but you can cut bread.

**What’s solid? Could you describe it?**

Solid is slippery, such as ice.
I don’t know.
Something is hard.
It’s hard stuff.
Like sugar.
What’s liquid? Could you describe it?

Like water. I feel pretty wet.
Oil
Lemon juice
Drink
Not hard, not soft, but you can feel it
Apple juice
Milk

What’s gas? Is gas and vapor the same?

Air
Oxygen. I don’t know what vapor is,
It can fly, not heavy. Don’t know what vapor is.
The diver with a bottle on his back, inside it is gas.
Gas is like air. It’s light, not heavy
I don’t know
Dangerous gas
Smoke. It’s easier to go away.

Those questions I asked you today are all related with chemistry? Is it interesting?

Somewhat interesting.
A little bit interesting.
Very much interesting. It’s fun.
Quite interesting. Quite fun.
Not interesting.
I only like ice cream chemistry.
Interesting, but It’s very good to learn knowledge as my sister said.

Did you know something about chemistry and lab?

I don’t know chemistry but I know something about lab, now I can’t remember it.
I don’t understand the word chemistry. From TV I see chemist working in the lab
I know the word chemistry. My dad works in the lab.
I have been to the children lab. We make water in the lab.
I have heard about chemistry in Finnish. I have been to bubbling chemistry lab before
They do science works in the lab.
I know the word chemistry. It is about soap, water, colour and food.
I have been to the lab for 2 times. Make cloud and make something better for the world.
Lab is a science place. Scientist makes things there.
I have heard so much. My sister is in grade 6. She learns chemistry. It’s very good to learn chemistry knowledge as my sister said.

If you have chance playing black game such as build a castle, you prefer to do it by yourself or together with your classmate? Why?

With my father. He is good at building. It’s fun..
Friends. It’s more fun.
I don’t like to do it alone. It’s nice to play with my friends.
Friends. Don’t want to play alone.
My self. I can do what I want to do
Friend. It’s good to give the chance to friend to play.
Myself. I don’t need to wait for my turn.
Some game you can’t play with your self.
Friends. It’s fun. I like teamwork. It’s surprising.
Myself. No one talking.
With my friends. If you play alone you have no one to play with. I feel lonely.
It’s not fun to play alone. It will finish quickly with friend.
Friends. I don’t want to do it alone. Sometimes we fight against each other, but afterward we come together again

Spot 8 differences with two pictures

A.3 Post –Test

What happens if we put sugar into the water? Is the weight same? Could we get the sugar back from the water?

The water keeps the sugar down. It’s not the same. No.
Taste good. Sugar is little and goes down. It’s not the same. No.
The sugar is in the water and goes away. It’s the same. No.
Water will up and sugar down. It’s the same. No.
It will become broken and come to liquids. It’s the same. No.
Taste different. Sugar is broken, not any more sugar. It’s the same. No.
It melts. It’s not the same. No.
Taste sweet. It’s not the same. No
Water mixes with the sugar. It’s the same. No.

What’s the difference between lemon juice and baking soda?
Baking soda like bad, lemon juice is good.
Lemon juice is sour, baking soda is not sour.
Lemon juice is wet; baking soda is not so wet.
Lemon juice is liquid, baking soda is not acid.
Lemon juice is liquid, baking soda isn’t liquid.
Taste different, baking soda is not soft as lemon juice.
Lemon juice is liquid and sour, baking soda is powder. The colour is different, the baking soda is white.
The colour is different, taste different.

**What’s the difference between liquid and gas?**

Gas is like air, liquid like water.
We can drink liquid but we can’t drink gas.
We can see liquid but we can’t see gas.
Liquid is visible and gas is invisible.
We can’t shake gas, but we can shake liquid.
Gas can fly. Liquid can drop down on the ground if it in the cup. If you pour liquid on your hair, you hair will become wet. If you pour gas on your hair, it will not wet.
Gas fly away need more spaces but liquid doesn’t need space.
Gas likes air, liquid likes water

**What happened to the baking soda when we put water inside the test tube? Any changes?**

Colour changed. Bubbles came out
It mixed with water.
Baking soda went down and water went up.
The baking soda went down to the bottom. The baking soda got wet.
Some baking soda melted, some didn’t, and some of them became liquid.
Baking soda melted and changed into liquid.
It will get small and small.
It was cloudy. There were more liquids.
Baking soda melted. The water was up.
It will come into bubbles if we put ice into the test tube.

**What happened when we mixed lemon juice with baking soda together? What’s inside the bubble?**

The colour became light. There was cold air in the bubble.
The colour changed. There was chemistry in the bubble.
Bubbles came out. There was gas inside the bubble.
Baking soda turned into liquid. There was gas inside the bubble.
Water in baking soda turned into pink. There was carbon dioxide inside the bubble.
It turned into grey. There was gas in the bubble.
There were a lot of bubbles. It was air inside the bubble.

*What is litmus? What the colour it is? How can we know lemon juice is acid?*

It’s purple.
Purple.
The lemon juice is sour.
It changes colour into lilac.
Yellow. The lemon juice is acid.
Purple. Lemon juice changes into red.
It’s liquid, the colour is purple, tell the thing we put in is sour or not. Lemon juice is acid.
I can’t remember. My short-memory is very bad.

**Something tastes sour is acid, true or false? Could you give examples?**

Acid is a new word for me.
I don’t know what’s acid.
Acid is sour.

**Is the baking soda acid? How can we know baking soda is not acid?**

Baking soda became red.
Litmus didn’t change.
It changed into purple.
No. It’s not acid.
It’s not acid. The colour changed.
Not acid. It changed into purple.
Yes. It is acid. The color didn’t change.

**Is dry ice ordinary ice?**

Very cold. Come into bubbles.
Not the same. It’s minus 79 centigrade.
It’s so cold. It will become into stream.
Very cold. It’s not the ordinarily ice, it is minus 79 centigrade.
Not ordinary ice. It’s so cold; your finger will be frozen if you touch it.
Not the same. It’s cold. It will turn into cloud.
Not the same. It will make sound if you touch it with lock.
No. This one is much cold.

**What happened to the ice after we put it into the water?**

Steam.
Air.
Go up.
It came into bubbles.
It came into pieces of ice and clouds.
It started to make clouds and melted.

**Liquids can change into gases, true or false? Could you give an example?**

False liquid like water, gas is not like water. Water can change into gas.
True I don’t know how to speak.
True Water can change into gas.
False It’s a kind of form; it can’t change to something else.
Liquids can change into solids, true or false? Could you give an example?

True. Frozen.
True. Water becomes ice.
True. I just guess, sometimes guess is better than saying I don’t know.
True. Water can change into ice.

Solids can change into gases. Could you give an example?

False. It’s hard.
False. Solid like something hard.
True. Water becomes ice and ice becomes gas.
True. Put the dry ice into the water it will turn into gas.

Solids change into liquids. Could you give an example?

True. Ice can change into water in the hot sun.
True. Ice can change into water if we put on fire.
True. Snow man is solid. It can melt into water.
True. If you put ice in the hot place, it will become into liquid.

Gases can change into Liquids. Could you give an example?

False. It was just gas.
False. We can’t feel gas but we can feel liquid.
True. Cloud becomes into rain.
False. It’s because the air can’t drop down.
False. Smoke can’t turn into liquid.
False. Gas like air, it can’t turn into liquid. It’s because it’s just air.
False. Gas isn’t like liquid.

We burn many candles during Christmas time. What happens to the candles? Where does it go?

It becomes small, start to become cloud.
Come into steam.
Just come to smoke.
Melt. It will go down.
Melt. It’s like cloud.
The fire melts it.
Melt. It will change into water, but we can’t drink it.
It melts into water but not safety water.
Burn out.
It melts and come into liquid. If you take it off it will dry and become hard.

Tell me what made the small “rocket” blasting off?

Bubbles.
The gas has no space.
Tablet and water.
The tablet made it flying.
Bubble exploded.

Gases can fill a container of any size and shape, true or false? Why?
True. If you put gas in the container, it will become more and more.
True. It can be big and can be small.
True. A lot of smoke can fill out a house.
False. It can fly, it disappears quickly.

Solids can hold its shape, true or false? Why?
True. I don’t know why.
False. I don’t know how to explain.

Liquids can hold its shape, true or false? Why?
True. The water falls down on the floor. If we tread on it, it will change its shape.
False. Liquid is just liquid.

Gases can hold its shape, true or false? Why?
True. Gas such as cloud has shape.
False. Sometimes cloud can change shape.
False. Gases go disappear.

We can compress solids, true or false? Why?
False. It’s not easy to compress solid.
True. Sometimes we can do it, such as compress sponge but not very easy.

We can compress liquids, true or false? Why?
True. Liquid is so soft.
False. The water will fall off my hand if I compress it.
False. Liquid can come out.

We can compress gases, true or false? Why?
False. We cannot compress balloon.
False. It’s like air, it will go through.
False. They will go thorough our finger.
False. We can’t touch gas. If you touch wind the wind will go through.
False. It will go away.

A.4 Interview

What do your dad and mum do?
My Dad is an English teacher; my mum will be a professor soon. My mum is ballet teacher, my dad helps the world. My mother studies tree, Dad works in Nokia. They do a lot of things and earn money to support us. Mum cooks, Dad watches TV. I don’t know.

**What’s your favorite hobby?**


**Did you like the guide? Why?**

She is nice. She is funny. She knows a lot of science.

**Are there any differences between the guide and your teacher in school? Why?**

My teacher is better. She teaches us a lot of things such as music, mathematics. Teacher teaches us how to learn, the guide teaches us how to do. Teacher teaches school things, the guide teaches science. There are no differences. We would have to listen and we can’t talk. They are different, because we can’t see the guide everyday. Their clothes are different.

**Did you learn something new today? Why?**

Yes, because we did experiments. A little. It’s because I already came here for 3 times.

**Did you enjoy studying in the lab? Why?**

It’s fun. I like science.

**Did you like doing experiments with your classmates in the lab? Why? What about doing by yourself?**

Yes. I can talk with my classmates. I don’t want to do it by myself. I don’t feel lonely if I do it with my classmates. We can discuss with each other. I prefer to do by myself. I can always get my turn. If I do something wrong, I can try it again. I like more doing it by myself. But it’s ok to cooperate with my classmate. I like to do by myself more. Today I didn’t do experiments with my friend. They are all boys,
I’m the only girl. I like girls more than boys. I like boys just because they are also human being.

**How important is it for students asking questions in the lab? Why?**

Somewhat important. Children ask more, they can learn more.  
Very important. You should ask if you don’t know how to do it.  
Important. If you don’t ask, then you will do something wrong.  
Not important. The most important thing is to listen. If you listen carefully, then you don’t need to ask question.  
Little important. It’s because children already know the answer.

**Why most of your classmates didn’t ask questions in the lab? Did you ask questions?**

Have nothing to ask. Children know the answer. I answered questions today.  
They are shy. I didn’t ask question.  
They don’t know how to say. I raised my hands for one time.  
I don’t know. But I asked question today.

**We will develop more new programmers in the future. Would you like to come to the lab again or not? Would you prefer to come with your parents or with your classmates?**

Yes. I hope I can come here everyday.  
Yes, with my parents.  
Yes, with my Dad.  
Yes, with my friends.

**A.5 Interview with Teachers**

How do you think about the bubbling chemistry?

Are there any advantages and disadvantages? Which part needs to improve in order to enhance science learning?

How do you think about discrepant events in the lab? Do you think it’s a good way to improve pupil’s problem solving ability?

Inquiry-based learning is very important for science education. Could you tell me why the kids didn’t ask questions in the lab?

Does the guide play a crucial role for encouraging the pupils to get involved in active learning?

Are there gender differences for learning in the lab?

Did bubbling chemistry fit in with the curriculum development in the school? Are there any differences between formal and informal learning?

How do you think about kitchen chemistry? By this way we can heighten the kids’ motivation and stimulate the pupil’s interest, do you agree or not?
Did pupils learn something new today?

What do you think is important for cognitive development?

Are there challenges for teaching students with different cultural backgrounds?

Is group work or peer study very important for studying in the lab? Why?

Children didn’t show creativity when they studied in the lab? Do you agree or disagree? How to improve it?

Did the pupils have their own scientific ideas before coming to the lab?

Did the pupils intrinsically motivated to study chemistry in the lab or just extrinsically motivated to do the experiments? How to prompt this kind of intrinsic motivation?

Did lab work improve pupils’ observation and predication abilities greatly?

How do you think about pupils’ positive attitudes toward science learning?

What’s the difference between teaching in the lab and in the school?

Did pupils really understand and remember these chemical concepts? Is it important for learning by understanding?

What do you think about learning by science playing?

A.6 Interview with the Guide

Are there any differences between international students and Finnish students? Which group is better?

Did the questions they answered satisfy your expectation? How did you encourage inquiry in the lab? Did inquiry-based learning effective?

Most of the kids didn’t ask questions in the lab. Do you have any new ideas for changing passive learning into active learning?

Is it the right time for the kids in this age group (7 years old) to know some chemical vocabularies?

Are there any gender differences for learning in the lab?

Do you think lab work could facilitate cognitive development?

What’s your opinion about their scientific process skills development in the lab?

Did you think kids have prior knowledge before studying chemistry in the lab? Did they have their own scientific ideas before?
Science thinking refers to reasoning ability, problem solving ability, prediction, classification, observation etc. Which one you think can be developed quickly in the lab?

Is it a good way for learning by science playing?

What’s the advantage for kids working in pairs? Is it very effective for peer learning in the lab?

What do you think about kitchen chemistry?

What about children’s fine motor skills development? For example, use spoon, pipette, etc.

Sometimes the kids got confused about litmus and food colouring even you already gave them a very nice instructions. Is it language problem or they just didn’t listen to you carefully?

What are the differences between teaching in the lab and in the classroom?

How do you think about discrepant events in the lab? Do you think it’s a good way to improve pupil’s problem solving ability?

A.7 Pictures