# THESIS

## USING VISUOSPATIAL MODELS TO ENHANCE TEACHING AND LEARNING OF ATOMIC STRUCTURE AND THE PERIODIC TABLE IN HIGH SCHOOL CHEMISTRY

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**GRADUATE SCHOOL, KASETSART UNIVERSITY**

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# THESIS APPROVAL

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THESIS

# USING VISUOSPATIAL MODELS TO ENHANCE TEACHING AND LEARNING OF ATOMIC STRUCTURE AND THE PERIODIC TABLE IN HIGH SCHOOL CHEMISTRY

PANWILAI CHOMCHID

A Thesis Submitted in Partial Fulfillment of
the Requirements for the degree of
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Atomic structure and the periodic table are very important topics for teaching and learning chemistry. Understanding the concepts of Atomic structure and the Periodic table will help students to understand advanced chemistry topics. Complementary research studies suggest that models and understanding modeling provide essential perspectives on conceptual development for students learning in chemistry. And, more recently, visualization and visuospatial thinking are adding another dimension for understanding learning in chemistry. In this study, the atomic structure and the periodic table instructional units (ASPTUs) using constructivist visuosaptial models, VAST-models and video animations were developed to enhance students' conceptual understanding and visuospatial thinking in atomic structure and the periodic table.

The ASPTUs were implemented by three volunteer chemistry teachers in three Grade 10 chemistry classrooms (44, 42, and 43 students) representing three different schools. The study provides a model for using constructivist visuospatial models for atomic structure and the periodic table instruction. Besides, the data of how do teacher implement, and students learn the ASPTUs as well as how can the instructional units promote students' understanding of concepts in atomic structure and the periodic table were explored. The teachers' teaching and students' learning were answered through classroom practice. Whereas the promotion of the instructional units was answered in term of students' conceptual understanding, students' visuospatial thinking of concepts, and students' perception of using the visuospatial models in their learning concepts of atomic structure and the periodic table.

The finding indicated that the visual representations VAST-models and video animations were mostly used for classroom discussions, detailing the experimental results, and used as a tool for inquiry. These visuospatial models facilitated students' conceptual learning and, by using multiple visual representations, students could achieve a deeper understanding of phenomena and concepts. Students' visuospatial abilities were significantly correlated with their performance in chemistry learning. Students with high spatial ability did better on chemistry tasks required problem solving skills rather than rote memory or the simple algorithms such as atomic structure and chemical periodicity of elements. Moreover, the preference is given to the dynamic VAST-models and video animations because they allowed for active inquiry and exchange of ideas. However, when visuospatial models are used in chemistry instruction, teachers should encourage students to focus on the visualization process and assist them to make cognitive connections between the models, their representations, and their chemistry concepts. Also, knowing students' existing understanding and concepts of atomic structure and the periodic, along with the students' visuospatial experiences and abilities prior to instruction should, enable teachers to adapt activities for addressing and enhancing students' performance.

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Student's Signature Thesis Advisor's Signature

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# CHAPTER I

# INTRODUCTION

This chapter describes the significance of this research study, regards the important of concepts in atomic structure and the periodic table for learning chemistry, the problems faced in the teaching and learning of these concepts both in Thailand and international. Besides, the outline of this thesis, the research purposes and the research questions are all discussed in this chapter.

## History of Chemistry

Chemistry is a discipline that studies matter and its properties. The history of chemistry provides a long pathway of thinking and discovery, beginning with, at least in recorded history the ancient Egyptians who knew how to work with and use metals. One of the first known metals that were purified by the Egyptians was gold. This was followed by the ancient Greeks. Greek philosophers had thoughts about elements and they proposed the existence of four forms; fire, air, earth, and water (Partington, 1989). Chemistry in Europe was prosperous in the period of alchemy-the period when early chemists tried to find out whether one element or metal could be transformed into gold. Although their attempts ended in failure they learned much about matter and its properties to further lay a foundation for the development of "modern" chemistry (Bowler & Morus, 2005).

### 1. Atomic Structure

In Western cultures, philosophers and scientists have thought about atoms with early Greeks offering their ideas concerning small indivisible particles that could not be further divided. In the history of developing visual representations for atomic structure, scientists began with three-dimensional representations, but text diagrams, explanations, and demonstrations have traditionally been two-dimensional for atomic structure. Those Greeks, such as Democritus, who thought about the existence of atoms described four elements (water, fire, earth, and wind) and described them as three-dimensional shapes giving attributes characteristic of their observed physical properties, such as a sphere representing water for its ability to move as a liquid, a sharp pointed pyramid for fire, and a cube for the solidness of earth. Dalton proposed that all atoms were spheres and each element or unique sphere had its characteristic properties. Succeeding accepted models in chemistry included Thomson's plum-pudding model and Bohr's planetary model. Currently, we continue to model atomic structure using three-dimensional representations and whereas textbooks use diagrams with multiple perspectives, visualization technologies now allow the quantum mechanical view for atomic structure to have dynamic characteristics representing its particle-wave duality properties. This visualization for atomic structure was derived through a mathematical equation developed by Schrödinger (Arabatzis, 2006; Asimov, 1992; Weinberg, 2003).

Atoms are made up of 3 types of particles electrons, protons and neutrons. These particles have different properties. Goldstein and Thomson's investigations utilized the cathode ray tube and, respectively, they identified two subatomic particles, the proton and electron. Electrons are tiny, very light particles that have a negative electrical charge (-). Protons are much larger and heavier than electrons and have the opposite charge, protons have a positive charge. Neutrons are large and heavy like protons; however neutrons have no electrical charge. Each atom is made up of a combination of these particles. Rutherford bombarded gold foil with alpha particles and determined that the dense atomic nucleus is surrounded by electrons. And, subsequent work by Bohr, lead to a model of electrons traveling around the nucleus analogous to planets revolving around the sun. The atomic number of an element refers to number of protons in the atom. The atomic mass is a sum of the mass of protons and neutrons in the nucleus. And, isotopes of atoms have the same atomic number, but different mass numbers because although the number of protons for each element remains constant, the number of protons can differ (Arabatzis, 2006; Asimov, 1992; Weinberg, 2003).

## 2. The Periodic Table

In textbooks and traditional instruction, the periodic table is a two-dimensional visualization that collectively can represent several properties for all the known elements. It typically includes a nominal symbolic scale (the names and symbols of elements), an ordinal scale (the atomic numbers and electron configurations); and an interval scale (atomic weight of the elements). However, the periodic table also quantitatively and qualitatively represents several periodic and group trends including changes in ionization energy, ionic size, electronegativity, atomic radius, shielding, and nuclear charge. With the introduction of new visualizations, such as animated videos, three-dimensional representations of the periodic table are now possible that are able to provide qualitative and quantitative perspectives of trends in the same view.

In terms of visualization, the periodic table can be considered to be a map of abstract relationships that requires the learner to develop new skills for determining spatial visualizations. Tversky (2005), describes these spatial relationships in visualization requires different levels of informational abstractions: categorical information, map abstract relations, and visualization. Categorical information refers to bar graphs in three-dimensional view as found in a periodic chart, contrast maps are a natural part of the periods found in the chart, and visualization preserves information at the internal level, where not only the order or objects but also the distance between objects and meaningful or at the ratio level, where zero, as well as order of elements is important, but the interval which can be units of one for the atomic number or indiscreet units associated with atomic mass, both being meaningful. When we look at the periodic table, even though the periodic table may typically be represented in two-dimensional, the actual elements are in a three-dimensional level of representation. The spatial relationships of visualizations are range from the two-dimensional element symbol and number to the three-dimensional atomic structure implied in the relationship of the electrons, neutrons, and electrons.

Mendeleev developed the periodic table using cards bearing data. Mendeleev began writing on the blank white surfaces of the cards. First he printed the chemical symbol of an element, then its atomic weight and finally a short list of its characteristic properties (Jensen, 2002; Strathern, 2000). However, being an organization of real matter, all having been created following the same laws of nature, the table helped to reveal other factors. Metals, gases, transition elements, and rare earths each found themselves in groups when arranged by mass. Even undiscovered elements were identified by empty spaces in the chart. Later, when arranged according to atomic number by others, the grouping improved, and this is used today. The modern periodic table arranges 109 elements by atomic number into seven horizontal rows and 18 vertical columns. Elements filling some of the gaps up to number 118 have been created in laboratories.

The periodic arrangement demonstrates trends revealing the physical and chemical properties of the elements such as atomic radii, ion radii, ionization energy, electron affinity, electro negativity, and physical state. Atomic radii and ion radii decrease across the period and increase along the groups, belong to effective nuclear charge. On the other hand, ionization energy and electro negativity increase across the period and decrease along the group. This is also because of the effect of effective nuclear charge. Electron affinity is a property of metal elements attraction with nonmetal elements during ionic bonding. It is increase belong to metallic characteristic of elements. The physical state of an element is related to the type of compound structure. The elements which are from metallic bonding and ionic bonding have a high melting point and boiling point. The covalent compounds have low melting point and boiling point. However, some covalent compounds have a high melting point and boiling point such as the carbon compounds, because they form a network of covalent bonding in the molecule’s structure (see Kotz, Treigchel, & Weaver, 2006; Whitten, Davis, Peck, & Stanley, 2004).

## The Important of Atomic Structure and the Periodic Table in Learning Chemistry

Chemistry is perceived to be a difficult subject to teach and learn internationally. There exist a multitude of factors that contribute to this perception. Perhaps the foremost reason is that chemistry is viewed as being a very abstract discipline because it relies so much on models (descriptive and diagrammatic) as representations for unobservable phenomena that require students to construct their own complementary mental models. For example, a typical chemistry laboratory activity might ask students to transform macroscopic observations to unobservable entities such as accounting for a color change based on a chemical reaction and relating it to changes in atomic structure and energy. In addition, the students' mental models need to incorporate various chemistry (e.g. molecules, elements and electrons) and mathematics' symbols (e.g. subscripts, exponential numbers, and units of measurement computations) to account for many of the interactions and relationships for the elements and atoms involved in the chemical changes.

To address instructional concerns for teachers and the problems associated with learning for students, researchers in science education have offered numerous research-based findings that offer new and varied perspectives to assist in changing chemistry instruction. For example, developing curriculum that reflects the historical development, arguments, and thinking in chemistry concerning atomic structure is one aspect (Niaz, 1998; Niaz, Agulera, Maza & Liendo, 2002) and is considered to be an approach that can facilitate students' understanding of chemistry as a way of thinking over time. A complementary view (Justi and Gilbert, 2002) comes from other researchers who suggest that models and understanding modeling can provide essential perspectives on not only the conceptual development of chemistry, but the scope and limitations for all models. In addition, they advocate that student's have opportunities to develop and test their own models. Another approach comes from investigations of students' conceptions of the periodic table and their difficulties in understanding isotopes and allotropes (Schmidt, Baumgartner, & Eybe, 2003). And, more recently, visualization (Gilbert, 2005) and visuospatial thinking are adding another dimension for understanding learning as "chemistry is the skillful study of symbolic transformations applied to graphic objects" (Hoffman, as cited in Kozma & Russell, 2005, p. 121).

With respect to current challenges for research and development in chemistry Justi and Gilbert (2002) advocate that issues regarding teachers and teacher education need to be addressed and pose the following four research questions: (1) How can teachers' notions of models and modeling be improved?, (2) How can teachers' pedagogical content knowledge about models and modeling be improved?, (3) How can teachers' instructional understanding and use of two-dimensional, three-dimensional, and dynamic (video simulations) forms of representation be improved with an emphasis on their critical analysis?, and (4) How can teachers' effectively introduce modeling in instruction such that students really understand the nature of chemistry from a critical perspective? Clearly these researchers and others are concerned with the current status of chemistry instruction and their perspective is that the practice of teaching be guided by research-based chemical education.

Understanding atomic structure and the periodic table are critical for learners of chemistry because these two topics serve as the foundation for effectively understanding and working in the discipline. And, since the two topics are foundational, atomic structure and the periodic table are characteristically found early in most course syllabi and chemistry instruction. The problem for students then, is that if they do not develop a firm foundation early on during instruction on atomic theory, the rest of chemistry can become a "muddle of discouragement." The goal of this research study is to investigate problems associated with teaching and learning of atomic structure and the periodic table and to determine if using visuospatial models (videos and VAST-models) can enhance instruction and learning of atomic structure and the periodic table in high school chemistry.

## Problem Statement

There are many research studies that have revealed problems in learning concepts in atomic structure and the periodic table. Students have alternative conceptions concerning atomic structure (Harrison & Treagust, 2000), do not understand the work of scientists on atomic structure (Niaz et al., 2002), cannot explain electron repulsion in valence shells (Peterson and Treagust, 1989), have misconceptions about atomic orbitals (Nakiboglu, 2003), have alternative conceptions about metals (Taber, 2002), and have even failed to distinguish between substances and atoms (Ahtee & Varjoli, 1998). Moreover, Chanthanapitan (1997) found that students in Thailand have alternative conceptions differentiating atomic size and molecular size. However, even though Thai chemistry education has rarely researched learning problems in the topics of atomic structure and the periodic table, data from the *NT test*[I] shows that Thai students are low in chemistry achievement. The average chemistry NT score in the academic year 2003, with 172,999 students tested in Basic Education Organization, had knowledge achievement at a level of 4.457 out of 16 possible points and their skills achievement was 8.716 out of 24 (Bureau of Education Testing, 2004). Thus, although Thai students consistently do poorly on national examinations, little is known about why this problem exists. However, teachers and students in the field have identified some factors that might assist them in teaching and learning chemistry: visualizations and hands-on models.

Chemical processes are paradigmatically represent by molecule and explained from a microscopic level. Various types of microscopic level such as structural formulas and ball-and-stick models are cultural tools for teacher to conduct students' inquiry (Nye, 1993). However, many studies mentioned the transitions between the three levels of representation in chemistry are found difficult by students to make. They were not able to move into and between the levels of representations. Numerous research studies have shown that students have problems in learning chemistry. While chemical phenomena can be represented at the macroscopic level, students find it

[I] The National Test (NT) is a standard test in Thailand aimed to assess students' knowledge and skills.

difficult to do so for the same phenomena at the sub-micro and symbolic levels (Ben-Zvi, Eylon, & Silberstein, 1988). Students find difficulty in understanding the concept represented in a given sub-mode at the sub-macro and symbolic levels (Kosma & Russell, 1997). In particular, they find difficulty with the interpresentation at the sub-micro-level of the reaction represented at the symbolic level (Krajcik, 1991); moving between the modes and sub-modes of representation a given molecule, What Siegal (1995) delightfully refers to as "transmediation", is found problematic (Keig & Rubba, 1993). Students are mentioned not able to understand microscopic representations (Ben-Zvi, Eylon, & Silberstein 1998; Komazma & Russell, 1997; Krajcik, 1991; Nakhleh, 1992). They had difficulties in interpreting representation (Ben-Zvi, Eylon, & Silberstein 1986) and also had a hard time to providing verbal explanation of chemical processes (Komazma & Russell, 1997). In additionally, Keig & Rubba (1993) mentioned that students unable making translations between different types of representations and also Kozma et al. (2000) referred to the lack of link among chemical phenomena, representations, and relevant concepts.

Wu and Shah (2004) summarized three majors alternative concept that arrive from difficulties in comprehending and interpreting representations: (1) representing chemical concepts at the macroscopic level rather than the microscopic or symbolic level; (2) comprehending visual representations at the macroscopic level and by surface features; and (3) interpreting chemical reactions as a static process. As mentioned before, symbolic and microscopic representations are frequency used in chemistry textbook. However, applying ideas of particles and constructing and constructing microscopic representation to make explanations of observation are difficult for students (Griffiths & Peterson, 1992) and usually they represent chemical concepts or phenomena at the macroscopic level rather than microscopic or symbolic levels (Krajcik,1991). Researches revealed students at secondary school level trough college level have alternative conception, comprehending visual representation at the macroscopic level by surface feature when they asked to interpret microscopic and symbolic representation (Kozma & Russell, 1997; Krajcik, 1991). Moreover, students had difficulties interpreting chemical equations (Krajcik, 1991). They interpret equation as a composition of letters, numbers and lines instead of process of bond chemical interaction. The technique of balancing chemical equations made students picture chemical equations as mathematical problems (Ben-Zvi, Eylon, & Silberstein 1986).

Chemistry curricula should guide students to use multiple representations visually and verbally conjunction with associated physical phenomena in classroom (Kozma, Russell, & Marx, 2000). A learning environment needs to explicitly demonstrate the conceptual relationship among representations at the macroscopic, molecular, and symbolic levels in a problem-solving or inquiry context. Through social and discursive practices, students have opportunities to conceptually move back and forth among three levels and cognitively interact with various types of representations in meaningful way.

## Out line of the Study

### 1. Study of Curriculum Development

According to the National Education Act B.E. 2542 (1999), Chapter 4, section 22 states that education shall be based on the principle that all learners are capable of learning and self development, and are regarded as being most important. The teaching and learning process shall aim at enabling the learners to develop themselves at their own pace and to the best of their potentiality. And moreover, in Chapter 4, Section 24, mentioned that to organize the learning process, educational institutions and agencies concerned shall organize activities for learner to draw from authentic experience; drill in practical work for complete mastery; enable learner to think critically and also enable instructor to create the ambiance, environment, instructional media, and facilities for learners to learn. To support the National Education Act, in Basic Education Curriculum B.E. 2544 (2001) mentioned that learning material should be varies and stimulate valuable learning, attraction, be thought provoking, easily and quickly, understandable; should motivate skillful search for knowledge; broaden learning scope, in depth, and continuously.

The organization responsible for developing the science curriculum in Thailand is the Institute for the Promotion of Teaching Science and Technology (IPST). The IPST sets the standards for teachers and students, provides core subject matter for basic education in Grades 1-12. The IPST science curriculum provides learning units, descriptions of the basic science courses, some example of lesson plans, and some example of evolution. However, teachers have to design themselves a lesson plans, science contents, classroom activities, teaching-learning materials, and assessments.

## 2. Professional Development

Professional development is a necessary process for educational improvement. Professional teachers require professional development for growth, changes in their teaching styles, learning new instructional and assessment techniques, and to reflect upon their own pedagogical content knowledge. Professional development programs need to be designed to focus on the particular needs. Teachers need the requisite knowledge, skills, behavior, and dispositions to support student learning and understanding of important science concepts and to assist in student's to master complex skills and reasoning processes that are essential for scientific literacy (Loucks-Hoursley, Love, Stiles, Mundry, & Hewson, 2003). Teachers need to have ownership in new versions of curricula and to feel competent to create appropriate learning environments for their students consistent with their own professional growth. This includes feeling secure in their knowledge of the content and supplementary materials they will use to help students learn with a focus on the students' future needs. This is an especially important reason why teachers need opportunities for professional growth. Professional development helps teachers learn what they need to know to achieve new vision, and to teach in ways that model how they can work with their students (Wilson, & Berne, 1999). The central purpose of professional development is to provide teachers with knowledge and skills they need to help students achieve high standards.

It is well known that every teaching situation is unique. Each day, in each classroom, particular combinations of factors occur. The personalities of both teachers and students interact with one other and with the content and activities of the science discipline that results in a unique environment. Decisions that teachers make in designing and executing instructional plans are far from trivial (Little, 1993; Danielson, 1996). However, all professional development programs need to consider the knowledge base and experience of the teachers and the learners with whom they will be teaching. Professional development is crucial on two levels: First, when teachers have learning experiences that help them understand how children best learn, they are better able to provide such experiences to their students (National Research Council, 2005). Second, professional development design should reflect how people learn so that the learners are supported to learn in a sustained and in depth ways (Loucks-Hoursley, Love, Stiles, Mundry, & Hewson, 2003; National Research Council, 2003). Therefore, the first very important consideration for the design of professional development is the knowledge base of the workshop participants. Effective professional development has seven components: (1) a well-defined image of classroom learning and teaching, (2) opportunities for teachers to build their content and pedagogical content knowledge, (3) there is research-based strategies for the teachers to use in their classroom practice, (4) there are opportunities for the teachers to collaborate with colleagues, (5) the professional development links with other parts of the educational system, (6) it allows for teachers to initiate leadership roles, and (7) the design is based on student learning and the data is used to continuously evaluate and improve classroom instruction (Loucks-Hoursley et al., 2003). These authors describe implementation of professional development processes following a sequence from committing to a vision, to analyzing student learning data, to goal setting, planning, doing, and evaluating. These processes are dynamic, data from each process can be use to reflect and improve upon the other processes.

In this research the participant chemistry teachers will be asked to attend a two-day professional development workshop. The workshop will include demonstrations and hands-on / minds-on work with a newly designed chemistry curriculum that has been developed for this research. It has been designed to reflect the identified needs of teachers and students in Thailand with a focus on atomic structure and periodicity instructional units and includes the use of models and videos. However, it is anticipated that the three participant chemistry teachers will conduct the chemistry curriculum in different ways from those demonstrated and reviewed in the workshop, reflecting their own professional perspectives. At the end of workshop, the teachers will be surveyed by a questionnaire and interviewed to assess both the effectiveness of the workshop and to gain insight into their anticipated use of the chemistry curriculum.

### 3. Participants of the Study

This research study was conducted in Nonthaburi Province, Thailand, Educational Area 1. The participant schools are classified as large size schools. In the year B.E. 2548 (2005), School A has 2,935 students, School B has 2,658 students, and School C has 2,088 students. The number of students in Grade 10 respectively, are School A = 499 (12classrooms), School B = 313 (8 classrooms), and School C = 272 (7 classrooms).

One teacher from each school (one male and two females) was participated in the research study. Each has different teaching experience and different chemistry teaching experience. Jandra the school A teacher, is a female teacher, has been teaching nearly thirty years, and has twelve years experience in chemistry teaching. Chuchart the school B teacher, is a male chemistry teacher, a novice teacher, in the semester of the study is his first fulltime teaching. However he has teaching experiences. And, Wanarat in School C is female and is very new in both teaching and chemistry teaching. She started teaching in 2005 and this year (2006) is the second year of her teaching.

Participant students were Grade 10 chemistry students in a fundamental chemistry course with each of the three chemistry teachers from the three schools. The research study will be conducted with students in one class per one chemistry teacher. There were 44, 42, 43 students per class in school A, school B, and school C, respectively.

## 4. Research Purposes

This study aimed to investigate the effective of instructional units using constructivist visuospatial model to enhance an instruction and learning atomic structure and periodic table. These following are the specific purposes of the study:

1. To investigate chemistry teachers' teaching of, and grade 10 chemistry students' learning of, concepts in atomic structure and the periodic table by the instructional units using constructivist visuospatial models in high school chemistry.

2. To promote grade 10 chemistry students' understanding of atomic structure and the periodic table concepts by using the atomic structure and the periodic table instructional units using constructivist visuospatial models.

## 5. Research Questions

The following question were investigated in the study

1. How do chemistry teachers implement a unit of instruction on atomic structure and the periodic table using constructivist visuospatial models?

2. How do grade 10 chemistry students learn a unit of instruction on atomic structure and the periodic table using constructivist visuospatial models?

3. How can a unit of instruction on atomic structure and the periodic table using constructivist visuospatial models promote grade 10 chemistry students' understanding of atomic structure and the periodic table?

3.1 What are students' understandings of concepts in atomic structure and the periodic table after learning by using the instructional units using constructivist visuospatial models?

3.2 What are students' perspective on the instructional units using constructivist visuospatial models help their learning concepts in atomic structure and the periodic table?

## 6. Operational Definitions

### 6.1 Visuospatial Models

Visuospatial Models consist of to part; video clip animations and VAST-models.

#### 6.1.1 Video Clip Animation

Video clip Animation is a video in the form of QuickTime program format. These videos include animation pictures and voice descriptions. Contents in the Video clip Animation Models include both atomic structure and the periodic table.

#### 6.1.2 VAST-models

VAST-models include three-dimensional-visualization hands on models for teaching and learning the historical development of atomic structure and the periodic table in chemistry. There are two components to the models, a teaching demonstration model and a model to be used by students for constructing the first twenty-one elements in the periodic table. Teacher and student handbooks accompany the models.

### 6.2 Instructional Units

Instructional units are teaching-learning units of atomic structure and periodic table concepts that consisted of learning plans, tasks, student book, test, laboratory equipments and instructional materials. The component of learning plan will consist of learning outcomes, content, teaching-learning activities, instructional materials, assessment, and learning resources. The content is separated into two parts. The first part is atomic structure and consists of four subtopics: subatomic particles, isotopes, electron configuration, and atomic models. The second part is periodic table which consists of three subtopics and includes the development of the periodic table, chemical properties of representative elements, and trends of periodic properties. These instructional units are based on the IPST science curriculum and use Visuospatial Models in teaching and learning processes.

### 6.3 Atomic Structure

Atomic structure is a topic in high school chemistry which consists of four subtopics; subatomic particles, isotopes, electron configuration, and atomic model concepts. These subtopics follow the IPST's science curriculum.

### 6.4 Periodic Table

Periodic table is a chemistry topic in high school chemistry which consists of three subtopics and includes the development of the periodic table, chemical properties of representative elements, and trends of periodic properties. All of these subtopics are based on IPST's science curriculum.

### 6.5 Learning

Learning refers to the methods student use to change their knowledge, and comprehension for the concepts of subatomic particles, isotopes, electron configuration, and atomic models, development of the periodic table, chemical properties of representative elements, and trends of periodic properties.

### 6.6 Visuospatial thinking

Visuospatial thinking is the mental visual image within memory and higher level cognition, includes (1) vision-using the eyes to identify, locate, and think about objects and ourselves in the world, and (2) imagery-the formation, inspection, transformation, and maintenance of image in the mind's eyes in the absence of a visual stimulus.

### 6.7 Understanding

Understanding refers to student conception of concepts in atomic structure and the periodic table.

## Significance of Study

As a research-based study, designed to follow the National Education Act and support the Basic Education Curriculum, the study as proposed provides a curriculum that is specifically designed to meet the specific needs of teachers in Thailand, but acknowledges that issues of learning abstract concepts in chemistry is a global issue in science education. This research is also important and interesting in that it will be using video clip animations and the VAST-models (Visualizing Atomic Structure Through Models) to teach chemistry in topics of atomic structure and the periodic table. The video clips are designed to accompany an introductory university General Chemistry textbook (Whitten, Davis, Peck, & Stanley, 2004). The researcher has permission to use and translate to Thai, these video clips to be used in the research. The researcher selected relevant video clips, make a voice over translation into Thai, and rerecorded them using a QuickTime program. The combined video clips together with PowerPoint presentations, and a historical development of ideas, adds a new dimension to teaching high school chemistry.

The VAST-models were constructed by the researcher. They include three-dimensional-visualization hands-on models for teaching and learning the historical development of atomic structure and the periodic table in chemistry.  There are two components to the models, a teaching demonstration model and a model to be used by students for constructing the first twenty-one elements in the periodic table. Teacher and student handbooks accompany the models. It is anticipated that the designed curriculum using video clips and VAST-models will, first of all, add an entirely new repertoire for teachers to use to facilitate classroom chemistry instruction of abstract concepts. And, second, the instructional units are designed to help students understand fundamental and important chemistry concepts in atomic structure and periodic table through the use of visuospatial models. The two topics, atomic structure and the periodic table, are foundational for understanding much of chemistry and tend to be limiting factors in determining whether or not students succeed or fail high school chemistry.

The benefits of using visuospatial representations in teaching chemistry are gaining recognition (Wu & Shah, 2004; Snir, Smith, & Raz, 2003; Hegarty, Carpenter, & Just, 1991) and researchers are currently investigating its many facets (Gilbert, 2005). The VAST-models and video clips should help students to understand the foundation of atomic structure and periodic table as well. In additionally the VAST-models are hands-on materials. Students can used the models to many concepts in atomic structure and periodic table; quantum number and atomic orbitals, atomic number, atomic mass, isotopes, electron configurations, valence electron, and position of elements in the periodic table. Moreover, the atomic structure and periodic table includes instructional units that the researcher developed with interesting activities.

Currently, there exists no cited research documentation of high school chemistry instructional material using models similar to the VAST-models for teaching atomic structure and periodic table. And, although the video clips are currently used to teach at the college level, the concepts are included in high school chemistry. The researcher feels that these videos should be able to enhance learning and understanding of chemistry for high school students. These instructional units are fully utilizing visuospatial learning, a new field of study in science education, and as such, this study will provide new dimensions and understanding to research in science education which should have an international impact.

# CHAPTER II

# LITERATURE REVIEW

This chapter reports review literature on education in Thailand, chemistry in the study and difficulties in learning chemistry. Along with these, constructivism and constructivist approach in chemistry learning as well as visualization in chemistry and visuospatial thinking are describes in this chapter.

## Education in Thailand

### 1. History of Thai Education

Thai education in the first period was no organization responded systematically, based on home, Buddhist temple and palace. Educational management, subjects, and scientific contents depended on the social environment and social needs. The idea to establish Thai education in system was started in the period of King Rama IV (1851-1868), at the time of colonial issue threatened countries in Southeast Asia. The King Rama IV realized that education is so important and could protect Thailand from colony hunting. The colonial issue became seriously in the period of King Rama V (1868-1910) and Thai education has been developed systematically at that time for survival from colony and for developing Thailand to be a civilization country. King Rama V asked Thai ambassadors of England and France to study education system of those two countries as a model for laying foundation of Thai education (ONEC, 20002). According to this point, Thai education has been developing from Education Project to National Education Plan to National Education Act.

The list following is the Thai Education Constitution Law (ONEC, 2002) since the first educational reform in Thailand since the period of King Rama V to now.

- Education Project B.E. 2441 (1898)
- Education Project B.E. 2445 (1902)

  - Education Project B.E. 2445, revised B.E. 2451 (1908)
  - Education Project B.E. 2445, revised B.E. 2452 (1909)
- Education Project B.E. 2456 (1922)
  - Education Project B.E. 2456, Revised B.E. 2458
- Education Project B.E. 2464 (1921)
- Education Plan B.E. 2475
- Education Plan B.E. 2479
- Education Plan B.E. 2494
- Education Plan B.E. 2503
- Education Plan B.E. 2520
- Education Plan B.E. 2435
- National Education Act B.E. 2542 (1999)

**2. Education Reform through National Education Act B.E. 2542 (1999)**

As education is the most important factor for the restructuring of the economy and society for sustainable development, Thailand must radically improve education and training systems as the foundation of national development. This is a priority because of rising economic and social problems, particularly because there exists an anticipated economic slowdown and rising unemployment. In response, the system of education and training must provide Thai people with self-sufficiency and adaptability.

In the Basic Education Curriculum, limitations and weakness of the old curriculum B.E. 2521 (revised B.E. 2523) implemented during the past ten years were identified. The limitations and weaknesses that researchers in the Department of Curriculum and Instruction Development identified at primary and secondary grades follow:

- The formulation of curriculum by central authorities does not reflect or respond to the needs of education institutions and provincial society.

– Curriculum and learning development in mathematics, science, and technologies fail to build up leaders in these fields. This necessitates the improvement of teaching and learning procedures in order to build up skills, creativities, and the right attitude among Thai people.

– The application of curriculum fails to foster the foundations of critical thinking, to create learning procedures in life skills and management, and to enable learners to effectively tackle fast changes in the social and economic areas.

– Foreign language learning, especially in the English language, fails to build up competencies in using languages for communication and seeking knowledge from various and extensive resource centers in the information age.

According to these views, Thailand had reformed education in 1999 and gave birth to the National Education Act B.E. 2542 (1999) (OEC, 2004, ONEC, 2001). In Section 28 of the National Education Act it is stated that curricula at all levels of education will be diversified and commensurate with each level, with the aim of improving the quality of life suitable for each individual's age and potential. The substance of the curricula, both academic and vocational, will be aimed at human development with a desirable balance regarding knowledge, critical thinking, capability, virtue and social responsibility. Apart from the characteristics mentioned above, the National Education Act requires that higher education curricula will emphasize academic development, with priority given to higher professions and research for development of the bodies of knowledge and society.

Through the National Education Act, the Basic Education Curriculum B.E 2544 was formulated in 2001. The curriculum is divided into four stages; each stage comprises three years, covering twelve years of basic education (Grade 1-12): primary Grade 1-3; primary Grade 4-6; secondary Grade 1-3; and secondary Grade 4-6. There are five groups of knowledge and skills as specified in the Section 23 of the National Education Act which are included in the Basic Education Curriculum. They are classified as sub-strands and divided into 8 groups of subjects: Thai Language;

Mathematics; Science; Social Studies; Religion and Culture; Health Education and Physical Education; Art; Career and Technology-Related Education; and Foreign Language. In addition, there is one activity focusing on developing learners in line with their interests such as those related to scouting and advice for further study. For each strand, the Basic Education Curriculum provides detailed explanations and outlines of sub-strands and standards.

## Chemistry in the Study

### 1. Chemistry in Thai Science Curriculum

The organization responsible for developing the science curriculum in Thailand is the Institute for the Promotion of Teaching Science and Technology (IPST, 2002). IPST sets the standards for teachers and students and also provides core subject matter for basic education in Grades 1-12 for all science sub-strands; Living Things and Living Processes, Life and Environment, Matter and Properties, Forces and Motion, Processes that Shape the Earth, Astronomy and Space, and Nature of Science and Technology. Each standard shares themes running from simple to more complex concepts for the different grades. Moreover, the IPST's science curriculum provides learning units, descriptions of the basic science courses, and lesson plans.

Chemistry is in the Sub-strand 3; Matter and Properties. Sub-stand 3 includes two science standards. Standard Science 3.1 emphasizes properties of matter, relationships between properties, structure, and forces among particles. The Standard Science 3.2 emphasizes the principal and nature of change of state in matter, formation of solutions, and chemical reactions. These content standards are taught in every grade level, but differ in detail and complexity. In the Standard Science for level standards Grade 1-3 toys are used to introduce matter. In level standards Grade 4-6, students learn about the states of matter. In the level standards Grade 7-6, students should be able to determine properties of matter by using senses and basic science instruments. In level standards Grade 10-6, students have to learn more abstract content and concepts, conduct experiments and be familiar with the science instruments used. These level standards are more complex.

## 2. Chemistry Topics in the Study

### 2.1 Atomic Structure

#### 2.1.1 Greek Model for the Atom

Some Greeks believed four elements existed: fire, water, earth, and air. Each element had a specific shape, fire was a pyramid with sharp jagged points representing pain, water was a sphere representing its ability to flow, earth was a cube to represent that it is solid and immovable, and air was a multi-sided figure representing its ability to move, but also cause disturbances as wind. For demonstration, the teacher may have the students observe and draw the different models and lead a discussion about the philosophies, assumptions, ideas, and evidence some Greeks, such as Democritus, may have used to construct their models and why other Greeks disagreed with their ideas. The Greeks did not have a model for atomic structure because the assumption was that the atom, itself, was indivisible. Similarly, their idea of the atom would not be considered to be a scientific theory because there was insufficient evidence or facts to support their models.

#### 2.1.2 Dalton's Model for the Atom

At the time of Dalton, the most accepted model for the atom was based on the corpuscular theory of Descartes who had proposed that the properties of substances depended upon the different shapes of their atoms, similar to the Greek models. Scientists had failed to find combinations of the four elements based on the Greek model, such as the products of fire-water. However, several new elements had been identified. Other new substances had also been proposed. For example, one theory postulated that flammable materials contained a substance called phlogiston was given off during combustion. Van Helmont believed that there were only two elements, water and air. And, he conducted a well known experiment in biology demonstrating that water was essential for plant growth, whereas very little soil was used.

Dalton performed experiments to investigate how elements reacted with one another. He studied the ratios in which elements combine in chemical reactions. Based on his results, In 1808 Dalton formulated Dalton's atomic theory, which is summarized in the following list.

– All elements are composed of tiny indivisible particles called atoms.

– Atoms of the same element are identical. The atoms of any one element are different from those of any other element.

– Atoms of different elements can physically mix together or can chemically combine with one another in sample whole number ratios to form compounds.

– Chemical reactions occur when atom are separated, joined, or rearranged. Atoms of one element, however, are never changed into atom of another element as a result of chemical reaction.

### 2.1.3 Thomson's Model for the Atom

Thomson passed an electric current through gases at low pressure in a cathode ray tube. He found that cathode rays are attracted to the anode that has positive electrical charge. The plates that carry a negative electrical charge repel the ray. So he proposed that a cathode ray is a stream of tiny negatively charged particles moving at high speed.

Thomson proposed a revised model, referred to as the "plum-pudding" atom. The plum-pudding atom had negatively charged electrons stuck into a lump of positively charged material, similar to raisins stuck in the dough.

### 2.1.4 Rutherford's Model for the Atom

Rutherford had established that alpha ($\alpha$) particles are positively charged particles. They are emitted at high kinetic energies by some radioactive atoms, that is, atoms that disintegrate spontaneously. He bombarded a very thin piece of gold with $\alpha$-particles from a radioactive source. A fluorescent zinc sulfide screen was placed behind the foil to indicate the scattering of the $\alpha$-particles by the gold foil. Scintillations (flashes) on the screen, caused by the individual $\alpha$-particles, were counted to determine the relative number of $\alpha$-particles deflected at the various angles. At the time, $\alpha$-particles were believed to be extremely dense, much denser than the gold atom. Quite unexpectedly, nearly all of the $\alpha$-particles were passed through the foil with little or no deflection. A few, however, were deflected at large angles, and very few $\alpha$-particles even return from the gold foil in the direction from which they had come.

Rutherford concluded that atom consist of very small, very dense positively charged nuclei surrounded by clouds of electrons at relatively large distances from the nuclei.

### 2.1.5 Bohr's Model for the Atom

In the meantime, scientists had another question, since protons and electrons have a different charge: "Why didn't the electrons fall down or get pulled into the nucleus?" Bohr tried to answer this question. He proposed that electrons are arranged in concentric circular paths, or orbits, around the nucleus in particular energy levels and perhaps their momentum kept them in orbit. This model was patterned after the motions of the planets around the sun. Bohr proposed that electrons in a particular path have a fixed energy; the electrons do not lose energy and can not fall into the nucleus. The energy level of an electron is the region around the nucleus where electron is most likely to be moving.

### 2.1.6 Schrödinger's Quantum Mechanical Model for the Atom

Schrödinger used a new way of thinking about mathematics and used quantum theory to write and solve a mathematical equation describing the location and energy of an electron in a hydrogen atom. The modern description for electrons in atoms, the quantum mechanical model, comes from the mathematical solution to Schrödinger's equation.

In the quantum mechanical model of the atom, the probability of finding an electron is that it is located within a certain volume of space surrounding the nucleus that can be represented as a fuzzy cloud. The cloud is denser where the probability of finding the electron is high. The cloud is less dense where the probability of finding the electron is low. Although it is unclear where the cloud ends, there is at least a slight chance of finding the electron a considerable distance from the nucleus. Therefore, attempts to show probabilities as a fuzzy cloud are unusually limited to the volume in which the electron is found 90% of the time. To visualize an electron probability cloud, imagine that you could mold a sack around the cloud so that the electron was inside the sack 90% of the time. The shape of the sack would then give you a useful picture of the shape of the cloud. These cloud shapes may, for example, be spheres or dumb-bells, depending upon the energy level of the electron. Illustrations of electron clouds typically show the shape in which the electron is found 90% of the time.

## 2.2 The Periodic Table

The first design of the periodic table was regarded as an ordering of the chemical elements demonstrating the periodicity of chemical and physical properties. Credit for the first periodic table probably should be given to a French geologist A.E. Beguyer de Chancourtois. In 1862, De Chancourtois presented his periodic table based on a helical graphic system in terms of increasing atomic weight. Unfortunately, his chart included some ions and compounds in addition to the elements. However, he was the first to recognize that the properties of the elements are a function of their atomic weight.

The first periodic system was presented by the German physicist Johann W. Dobereiner in 1817. Dobereiner recognized a relationship between atomic weights and chemical properties. He observed that, in a set of three elements whose chemical properties were similar, the atomic weight of the second member of the "triad" was almost exactly the mean of the atomic weights of the first and third elements. For example, for the elements calcium, strontium, and barium, the atomic weight of strontium was an average of calcium and barium. However, a major problem with such classifications was that the atomic weights were not yet determined correctly, nor were they well understood, because Dalton’s atomic theory was too recent to have been conclusively demonstrated.

Later in 1864, John Newlands the English chemist came up the law of octaves, according to which properties of the elements are repeated after each series of seven elements. Newlands arranged the known elements by atomic weights. In doing so, he noticed some recurring patterns, and the patterns were such that if he broke up his list of elements into groups of seven (starting a new row with the eighth element), the first elements in each of those groups were similar to one another. So was the second element in each group and the third and so on.

Interestingly, also in 1864 the German chemist Julius Lothar Meyer presented his textbook, which included an abbreviated version of a periodic table used to classify the elements. This consisted of 28 elements listed in order of their atomic weight and demonstrated periodic valence changes (for example sodium forms a chloride NaCl and has a valency of one) as a function of atomic weight. In 1868, Meyer constructed an extended table which incorporated transition metals, shown in the table 2.2. This table was earlier than Mendeleev's periodic table (1869) but unfortunately Meyer's was not published until 1870.

Dmitri Mendeleev, a German chemist, found a way to relate the elements in a systematic, logical way after many years of hard work. It is important to recall that most of the pioneering work of Mendeleev was conducted from 1869 to 1889, before Thomson (1897), Rutherford (1911), and Bohr (1913) laid the foundation of modern atomic theory. How, then, did Medeleev conceptualize periodicity as a function of atomic theory?

Mendeleev listed the elements in each column in order of increasing atomic mass. He then arranged the columns so that the elements with the most similar properties were side by side. He thus constructed the periodic table, an arrangement of the elements according to similarities in their properties. Mendeleev left blank spaces in the table wherever there was no known element with the appropriate properties and mass. For this work Mendeleev was named “the father of the periodic table”.

Based on his table, Medeleev was able to predict the physical and chemical properties of the missing elements. Eventually these elements were discovered and were found to have properties similar to those predicted. The following are the most important:

– Eka-aluminum (atomic weight = 68, density = 6.0, atomic volume = 11.5). This was discovered by the French chemist Paul Emile Lecoq de Boisbaudran in 1875, and was named gallium.

– Eka-boron (atomic weight = 44, density = 3.5. This was discovered by the Swedish chemist Lars-Frederick Nilson in 1879, and was named scandium.

– Eka-silicon (atomic weight = 72, density = 5.5, atomic volume = 13). This was discovered by the German chemist Clemens Alexander Winkler in 1886, and was named Germanium.

There has been some disagreement about who deserves credit for being the "father" of the periodic table, Meyer or Mendeleev. Both chemists produced remarkably similar results at the same time working independently of one another. Unlike Meyer who was more impressed by the periodicity of the physical properties of the elements, Mendeleyev saw more clearly the chemical consequences of the periodic law. Unfortunately for Meyer, Mendeleev's table became available to the scientific community via publication (1869) before Meyer's appeared (1870).

Almost fifty years after Mendeleev, the periodic table was developed further by the British chemist Henry Moseley (1887-1951), a student of Rutherford. In 1913, Moseley was able to derive the relationship between x-ray frequency and number of protons (atomic number) of elements. He arranged the elements in a periodic table by order of atomic number instead of atomic mass which Mendeleev had used. Nowadays, the modern periodic table is based on Moseley's periodic law.

The American chemist Glenn T. Seaborg made the last major change to the periodic table when he added the lanthanide series and actinide series into the periodic table in 1945 to accommodate the new discoveries from irradiating uranium, the transuranium elements (neptunium, plutonium, americium, curium, berkelium, and californium).

## 3. Difficulties in Learning in Chemistry

### 3.1 Difficulties in Learning in Chemistry in Thailand

As previously stated, atomic structure and the periodic table typically occur early in syllabi internationally, including Thailand (IPST, 2002). Early in this research study, a survey of chemistry teachers was conducted in Surin Province, Educational Area 1, Thailand. The teachers identified atomic structure and the periodic table as being two important and problematic topics to teach, and for students to understand. They stated the concepts in atomic structure and the periodic table are too abstract and that they also have a problem in designing experiences needed for students to develop a meaningful understanding of these two foundational topics. One teacher’s comment reflects a consensus;

> "...the concepts are very abstract. Students have to use their imagination to make understanding. I don’t know how to make instructional materials to help them understand the concepts better".

This survey data supports what other researchers have reported with problems associated in teaching and learning chemistry. The highest number of teaching problems that these teachers encounter in teaching atomic structure and periodic table are lack of concrete instructional materials. Moreover, in a question about need in teaching formats, the highly ranked teaching format that teachers want to use in teaching atomic structure and the periodic table is that of computer visuals for instruction. Teachers wanted more technology and hands-on materials to use in teaching. Unfortunately, from the survey data of the researcher, it seems teachers are not ready to do those themselves, especially teaching-learning materials construction (Chomchid, Inyega, & Thomson, 2005).

### 3.2 Difficulties in Learning in Chemistry in International

Especially, the chemistry text book, the researcher constructed textbook based on the research with mention the lack of history and philosophy in developing knowledge in atomic structure and periodic table (Niaz, 1998; Brito, Rodriguez, & Niaz, 2005). The instructional unit will also facilitate students to understand concepts in atomic structure and periodic table as well. Moreover, many researches mentioned students often have difficulty understanding abstract concepts of chemistry, both high school and college levels. The studies indicated that students tend to experience difficulty with spatially-related chemistry problems requiring three-dimensional thinking (Ben-Zvi, Eylon, & Silberstein 1998; Komazma & Russell, 1997; Krajcik, 1991). In addition, the researchers suggested to aid the students with these abstract concepts, visualization tools have been found to increase students' learning. There are many strategies have been suggested; adapting strategies based on the conceptual models and using technology tool (Krajcik,1991), using multimedia-base instructional (Ardac & Akaygum, 2004), using computer-assisted instruction - CAI (Yalcinalp, Geban, & Ozkan,1995), using microcomputer-base laboratory – MBL (Roth & Roth,1995, Nakhleh & Krajcik ,1994), using visualizing tool (Wu et al, 2000; Gilbert & Osborne, 1980), and using computer animations (Williamson & Abraham,1995). Wu and Shah (2004) categorize visualization tools into three types (1) concrete models: visualizing three-dimensional configuration of molecule; (2) animation: visualization the dynamic nature of chemical processes, and (3) Computer based visualization tools: model construction tools, multimedia learning tools, and learning environments.

## Constructivism

Constructivists focus on the process are created, negotiated, sustained, and modified within a specific context of human action. Constructivist believes that to understand this world of meaning one must be interpret it. The ways of experiencing action in society are expressed in the language and descriptions constitutive of institutions and practices (Schwandt, 1994). Constructivist is deeply committed to the contrary view that what we take to be objective knowledge and truth is the result of perspective. Knowledge and truth are created not discover by mind, ideas are invented rather than discovers under the heading of natural inquiry. Constructivism means that human beings do not find or discover knowledge so much as construct or make it. Learners invent concepts, models, and schemes to make sense of experience and, future, continually test and modify the constructions in the light of new experiences. To construct something that works cognitively, that fit together and handles new cases that may implement further inquiry and invention. There are two different views of how students construct their knowledge. The two most comprehensive and best know of constructivism are called radical constructivism and social constructionism (Staver, 1998).

### 1. Radical Constructivism

The leading proponent of radical constructivism is Ernst von Glasersfeld (Staver, 1998). von Glasersfeld (1991) defined radical constructivism as the contrast between view of mind as the vessel for the acquisition, storage, and retrieval of information and an instrumentalist notion of mind as an active creator and manipulator of symbols are taken up in a version of constructivist thinking. Von Glasersfeld looks at radical constructivism as a relationship between mind and world. He claimed that we can not know such as a thing as an independent, objective world that stand apart from we experiences of it, we can not speak of knowledge as some how corresponding to, mirroring, or representing that world. In von Glasersfeld view knowledge is actively built up from within by a thinking person; knowledge is not passively received through the senses or by any form of communication. (Staver, 1998). Primary emphasis of radical constructivism is on the mental process of the individuals and the way in which they construct knowledge of the world from within (Gergen, 1995; Staver, 1998). Radical constructivism rejects the notion that knowledge ought to be a veridical representation of a world as it exists prior to being experienced. Knowledge is not particular kind of product that exists independent of the knower but an activity or process. The validity of knowledge claim is not to be found in the relationship of reference or correspondence to an independently existing world; rather, a claim is thought to be valid if it is viable of if it provides function fit, that is, if it works to achieve a goal. The relationship between knowledge and reality is instrumental, not verificative. To know is to posses ways and means of acting and thinking that allow one to attain the goals one happen to have chosen (Schwandt, 1994).

**2. Social Constructionism**

The leading proponent of social constructioninsm, Kenneth Gergen (1995) challenged the idea of some objective basis for knowledge claims and examines the process of knowledge construction. Instead of focusing on the matter of individual minds and cognitive processes, Gergen turn attention to the world of intersubjectively shared, social constructions of meaning and knowledge. In opposite ways of focusing on individual mind and cognitive processes, social constructionism attention to the world of intersubjectively shared (Schwandt, 1994). The social constructionist approach is predicated the assumption that the term by which the world is understood are social artifacts, products of historically situated interchanges among people. Knowledge is one of the many coordinated activities of individual and as such is a subject to the same processes that characterize any human interaction. Focus of a social constructionism is not on the meaning-making activity of the individual mind but on the collective generation of meaning as shaped by convention of language and other social processes (Staver, 1998).

Although von Glasersfeld and Gergen emphasized different versions of constructivist philosophy, both of them discussed their approach under the inquiry (Schwandt, 1994). Even though the pathways of constructing knowledge are different; self construction or social construction, inquiry is the way to contribute knowledge.

### 3. Constructivist Learning

To understand how students learn acquire knowledge is always an important issue in science education. Constructivism is a theory about knowing and learning concern that knowledge can not be directly transmitted but must be actively constructed by learners. Constructivism begins with the premise that the human world is different from the natural, physical world and therefore must be study differently. Constructivist learning is the multiple realities constructed by people and implications of those constructions for their live and interactions with others (Patton, 2002). It is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction (Von Glasersfeld, 1995). Constructivist view of learning is also emphasizes the significant of the individual learner's prior knowledge (Wu &Tsai, 2005). Constructivist teaching is guided by five basic elements; (1) activating prior knowledge, (2) acquiring knowledge, (3) understanding knowledge, (4) using knowledge, and (5) reflecting on knowledge (Tolman & Hardy, 1995). Constructivist learning environments are clearly beneficial for students (Resenfeld & Resenfeld, 2006).

To reach the constructivist learning, inquiry process is needed. The National Science Education Standard (National Research Council, 2000) stated that scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations base 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. Teaching science through inquiry allows students to conceptualize a question and then seek possible explanations that response to that question. Students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking the explanation of human knowledge of the natural world. Learning environments that concentrate on conveying to students what scientists already know do not promote inquiry. Rather an emphasis on inquiry asks that we think about what we know, why we know, and how we have come to know. An inquiry approach to the scientific process requires that students learn to ask questions, plan their investigations, use resources to find information, analyze data, communicate result, and recognize and analyze alternative explanations and prediction (Varelas, Becker, Luster, & Wenzel, 2002; Puntambekar & Kolodner, 2005). Opportunities to learn science as a process of inquiry has important advantages. It involves observation, imagination, and reasoning about the phenomena under the study. It includes the use of tools and procedure. The context of authentic inquiry becomes devices that allow students to extend their everyday experiences of the world and help them organize data in ways that provide new insights phenomena (Bransford & Donovan, 2005).

To guided inquiry into the science classroom Minstrell and Kraus (2005) suggested that teachers need to ask students if they want to know what students are thinking. To assert learning as an active process, teachers need to acknowledge students' attempts to make sense of their experience and help them confront in consistencies in their sense making. Teacher questions can model the sorts of questions students might ask themselves when conducting personal inquiry. Teachers need to know students' initial and developing conceptions. Students need to have their initial ideas brought to a conscious level. Students need opportunities to explore the relationship among ideas. Teachers should remember that students are more likely to share their thinking in a climate where others express genuine interest in what they have to say. Waiting until one student has completely expressed his or her idea fosters deeper thinking on that speaker's part. Teachers should ask speaker critical questions to clarify what they are saying or to help them give more complete answers and explanations fosters their own engagement and learning. It is important to give students opportunities to apply (without being told, if possible) ideas leaned earlier. Students should be provides opportunities to differentiate between summarizing observable result and the conclusions generalized from those result. After students had experiences and come up with ideas to summarize those experiences, it makes sense to introduce a technical term of communication. When complex explanations involving several factors are need for their reasoning, students need more time to put the piece together. Students need opportunities to reflect on and summarize what they have learned. Finally, assessment should help the teacher monitor whether students are still operating on the basic of preconceptions, as well as whether they have attained the learning goal.

## Visuospatial Model

Visuospatial or visual-spatial is the combined of visualization and spatial (Mathewson, 1999). Visualization is a powerful tool that can facilitate processes of constructing and reconstructing successful relationships between relevant declarative and procedural knowledge (Lavoie, 1995). In this sense, declarative knowledge consists of the specific facts and concepts associated with a discipline and procedural knowledge consists of knowing how, when, and why the facts and concepts may be used. The role of visualization in science and science education has become an important, active, and productive area of research as not only have theoretical (epistemological and ontological) frameworks emerged to provide lens through which to investigate phenomena within science, but it also offers new ways of viewing learning and understanding scientific inquiry including the use of models in scientific representation (Gilbert, 2005; Passmore & Stewart, 2002). Furthermore, visualization also offers an entirely new dimension for students to explore and engage in scientific inquiry (Gilbert, 2005; White & Frederiksen, 1998).

## 1. Meaning of Visualization

What does visualization mean? Currently, visualization is thought of as including three domains: external and internal representations and the spatial (physical and metacognitive) skills one needs to work with and link to the external and internal representations (Gobert, 2005). More specifically, (1) external representations refer not only to the physical models, graphics, diagrams, PowerPoint presentations, and videos scientists construct in doing science, but also those representations teachers and students use for instruction and learning; (2) internal representations refer to the mental constructs and representations scientists / teachers / students develop and use in their construction and understanding of natural phenomena such as atomic structure and the periodic table (these representations may be as propositional/semantic or visual forms); and (3) spatial skill refers to the ability students have for manipulating or transforming images or spatial patterns into other arrangements, such as interpreting how a two-dimensional textbook diagram for atomic structure can be compared to a three-dimensional physical model.

## 2. Visualization in Chemistry

In chemistry visualization, three levels of representation can be considered: the macroscopic, microscopic, and symbolic levels (Johnstone, 1993; Gabel, 1999, Gobert, 2005). Chemical representations at the macroscopic level refer to observable phenomena and range from laboratory activities and experiments such as chemical reactions and their associated color changes to the pictures and diagrams teachers and students use in textbooks or construct on blackboards. Microscopic representations in chemistry can refer to those models or other visual displays that depict the arrangement and movement of particles. Chemical representations at the symbolic level include symbols, numbers, and signs used to represent atoms, molecules, compounds, and chemical processes, such as chemical symbols, formulas, and chemical structures.

In teaching science, models become vital if the visualization of entities within exemplar phenomena take place (Gilbert, 2005). The development of models and representation of them are crucial in the production of meaningful knowledge. Models can function as a bridge between the scientific theory and the world as experienced. They can act as simplified depictions for abstract theory and they can also be idealizations of a reality as imagined, based on the abstraction of a theory. Models can also depict many different classes of entities, covering both macro- and micro- levels of representation. Cartier, Rudolph, & Stewart (2001) have expanded the concept and use of scientific models to include the set of ideas that may be used to describe a natural phenomenon: (1) a scientific model is a set of ideas that describes a natural process; (2) models are constituted by empirical or theoretical objects and the processes in which they participate; (3) models can be used to explain and predict natural phenomena; (4) models are consistently assessed on the basis of empirical and conceptual criteria. And (5) models are also useful as guides to future research.

Gilbert (2005) has stated that visualization is especially central to learning in science. And, chemistry is a particularly visual science because visualization plays a major role in the daily practice of chemistry (Wu & Shah, 2004). To investigate natural phenomena through ideas of molecules, atoms, subatomic particles, and the relationships amongst them, visualization is essential for the communication of concepts to students in chemistry. For example, representations using pictures, diagrams, flow charts, and chemical formulae and symbols are as integral to learning and understanding as the printed descriptions found in chemistry textbooks. Use of visuospatial models for learning and understanding chemistry is becoming an essential component for instruction with increasing availability of technologies and, subsequently, an area of research into learning in chemistry. For example, Wu and Shah (2004) have investigated the relationship of visuospatial thinking to constructing meaningful understanding. They propose that in designing chemistry visualization tools for facilitating student understanding: (1) multiple representations and descriptions should be provided, (2) linked referential connections must be visible, (3), presentation of chemistry should be interactive and dynamic reflecting the nature of chemistry, (4) students need to have explicit instruction in making transformations between two-dimensional and three-dimensional models, and (5) the cognitive difficulty of chemistry can be reduced by making information explicit and integrative for students. They also propose that in chemistry, visuospatial abilities are relevant to learning and that some visualization tools have been effective in helping students overcome conceptual errors.

Visuospatial models help students engage with fundamental ideas, especially, for students who have developed relevant macroscopic conceptions and interrelated conceptions (Snir, Smith, & Raz, 2003). Visual representations in chemistry, such as molecular structures and atomic models are partially schematized and partially iconic diagrams that depict abstract concepts and apply conventions to illustrate both their components and organization (Hegarty, Carpenter, & Just, 1991, as cited in Wu & Shah, 2004) are difficult because it requires that students visuospatial models are linked to particular cognitive operations spatially that may already exist in some form in the students construct. Cartier et al. (2001) suggest that curricula which includes sets of model representations provide students with opportunities to learn about the conceptual subject matter of particular disciplines and the nature of scientific knowledge. In one study (Copolo & Hounshell, 1995), it was determined that students using combinations of three dimensional ball and stick models with three dimensional isomeric molecular computer models scored significantly higher in understanding and retention than those using two dimensional models.

### 3. Model in Chemistry Learning

Halloun (2004) stated that scientific model is a conception system. It is composed of conceptions represent primary features of the modeled pattern. Primary features are features that common to all systems in the model represent to classes and are responsible for producing the pattern, included certain bodies (objects and agents) and/or field, in the make-up of models referents, and system they belong to. This is the model from the perspective of what scientists actually do. Scientific model makes up or contributes to scientific practice. It is a set of ideas that describes a natural process (Cartier, Rudolph, & Stewart, 2001). Models are experimental evidence constituted by empirical or theorithical objects and the processes in which they participate. They contain abstract elements that can not be visualized. They can be used to explain and predict natural phenomena (Carter, Rudolph, & Stewart, 2001; Johnson-Laird, 1996).

### 3.1 Modes of Model Representation

Gilbert (2005) specified the models' version of a phenomenon in the public domain in five modes of representation.

– The concrete mode is three-dimensional and made of resistant materials e.g. a plastic ball-and-stick model of an ion lattice.

– The verbal mode can consist of a description of the entities and the relationships between them in a representation e.g. of the natures of the balls and sticks in a ball-and-stick representation it can also consist of an exploration of the metaphors and analogies on which the model is based e.g. covalent bonding.

– The symbolic mode consists of chemical symbols and formula, chemical equations, and the mathematical expression e.g. the universal gas law.

– The visual mode makes use of graphs, diagram, and animations e.g. two-dimensional of chemical structure.

– The gesture mode makes use movement by the body or its part e.g. of ions during electrolysis by school pupils moving in the counter-flows.

### 3.2 Models and Symbol Use in Atomic Structure and the Periodic Table

As chemistry is very abstract scientific content. To deal with properties and transformation of materials which change in the molecules and atoms, no one can observe directly. The explanation of the natures of substance and their transformation are essentially abstract. This is the reason why chemists' model both phenomena they observe and the ideas with which they try to explain such phenomena that is at both macroscopic and microscopic levels by the use of analogy wit what they already know (Justi & Gilbert, 2002). They try to express chemical phenomena in a concrete, visual, mathematical form, and verbal mode of representation, and sometimes using special symbols that constitute chemical language (e.g. formulae of elements and compounds). Thus chemical knowledge about range of phenomena is produce and communicates with the use of several models. Models enable chemist to predict behaviors of substances and to speculate the spatial arrangements of atom and molecules. Molecular models thus became obligatory tools in the study of the study of stereochemistry, properties, and reactivity of substances which corroborated the atomic structure (Justi & Gilbert, 2002). Modeling is one of main processes in the development of scientific knowledge.

In the study of atomic structures, the first concrete scientific models for atoms by Dalton at the beginning of the nineteen century (IPST, 2004; Whitten, Davis, Peck, & Stanley, 2004; Wilbraham, Staley, Matta, & Waterman, 2002; Asimov, 1992) was a landmark in the way that models have contribute to the development of chemical knowledge. Follow by atomic model of Thomson, Rutherford, Bohr, and the seasonally atomic model in this time is quantum mechanical view of atom of Schrödinger. The model of atomic structure enables chemists to understand more clearly about the mystery in atom, and behavior (properties) of their subatomic particle that affected the properties of elements and compounds.

Symbol play important role in the study of the periodic table. Chemists use symbol to represent all elements in the periodic table. The alphabet character symbol for elements represent whole things of those elements. More over, all chemists agree that the periodic table is the heart of chemistry which is benefit to study chemistry. The position of element in the periodic table is not just only show where the elements live but we can use the periodic table to predict properties of elements e.g. size, melting point, boiling point, density, etc like a magic. The fist model of the periodic table credit to Newland who try to use octave law to put elements into the periodic table, later Meyer and Medeleev developed their own periodic table models (Jensen, 2005; IPST, 2002; Wilbraham, Staley, Matta, & Waterman, 2002), and now the new periodic table complete by Seaborg to add transuranium elements, lanthanide and actinide elements into the periodic table (Whitten, Davis, Peck, & Stanley, 2004).

**4. Use of Videos in Learning Chemistry**

Videos have become an integral component for teaching and learning in the classroom because videos can show information that is otherwise in accessible with regard to time, space, and matter. For example, using QuickTime videos, animations may provide comparisons of 2- and 3-dimensional views of molecules or they may be reversed or stopped in the middle of a representation of a molecular / chemical reaction or process to demonstrate time-space-matter relationships that are unobservable to the naked eye. The goal of showing students pictures or movies is to draw out important ideas, stimulate creative thought, and promote meaningful conceptual linkages within a particular context. Research investigating the use of videos in cognitive science has determined that they lead to more elaborate and explicit knowledge relationships than is possible through audio, verbal or textual means alone. The information contained in visuals is inherently high density and there are more opportunities for the learner to establish linkages with pre-existing knowledge (Lavoie, 1995). Science teaching should be concurrent with visual aids during all phases of instruction and at all levels of cognitive development. Video technology combined with appropriate teaching and learning strategies, can be use to be achieve high levels of visual interactivity, and it then becomes an effective vehicle for delivering anchored instruction-instruction that provides students with a focus on inquiry. It helps the student in the identification and application of visual information that is relevant to solving a posed problem (Brandsford, Sherwood, Hasselbring, Kinser, & Williams, 1990). Teachers can increase visual interactivities by asking appropriate divergent and convergent questions, giving opportunities for feedback and posing visually-oriented problems.

Video is typically multi-dimensional being composed of a variety of simulated and animate processes, still pictures, motion pictures, and dynamic graphics. The advantage of videos over printed media is that an animate or real-life experience can be slowed-down, sped-up, frozen, manipulated, and experimented with in the context of time and space. Videos also allow students to explore and discover concepts in real world contexts that would otherwise concern safety, time, expense, or accessibility (Livoie, 1995; Escalada, Rebello, & Zollman, 1996; Escalada & Zollman, 1997). Using videos in teaching is also useful for improving students' visuospatial skills, providing techniques for creative visualization, and allowing the use of various visual-learning modes. Video not only provides opportunities for students to not only develop their understanding and reinforcement of scientific concepts, but also allows them to develop their skills in scientific investigation and inquiry (Escalada & Zollman, 1997).

There are two common strategies for using video in the science classroom: video images and video-based laboratory tools. Video images are frequently called "video or image processing". With appropriate software, students can combine images from different video frames and modify the presentation of motion on the screen. These techniques have been used on concrete representations similar to the space-time diagrams, and to change synthetically the reference frame from which students can view an event (Escalada, Zollman, & Grabhorn, 1996; Chaudhury & Zollman, 1994). The video-based laboratory tools enable students to connect any video source-camera, videocassette recorder, or videodisc player, and digitize the incoming analog signal. The resulting digital data are stored on the hard drive of the computer. Then students can produce real-time graphs of the motion of objects being investigated (Chaudhury & Zollman, 1994). Clearly, videos and their tools offer new dimensions to both learners and researchers interested in understanding their impact on learning in chemistry.

## 5. Use of Hands-on Models in Learning Chemistry

At a fundamental level, hands-on quite literally means students "manipulate" the things they are studying and "handle" scientific instruments (John, Andre, Kubasko, Bokinsky, Treatter, Negishi, Taylor, & Superfine, 2004). The concept of hands-on science is based on the methods students employ to make sense of the world around them. These experiences should allow students to be actively engaged in the manipulation of everyday objects and materials from the real world. This physical manipulation and handling of objects is an effective way for students to learn science (Vesilind, & Jones, 1996). When students do hands-on science they are typically holding, touching, moving, observing, listening, smelling, and sometimes tasting objects under investigation. This use of multiple senses in learning is often considered to be part of the developmental process of moving from concrete to abstract thinking (Loucks-Horsley, Kapitan, Carlson, Kuerbis, Clark, Melle, Sache, & Walton, 1990).

To aid students with abstract concepts in chemistry, manipulatives are often advocated as instructional tools. Manipulative have been found to increase students' learning significantly and most often in chemistry, they are concrete hands-on models such as hand-made paper models, styrofoam ball and pipe cleaner models, and various commercial ball and stick models (Steff, Bateman, Uttal, 2005; Copolo & Hounshell, 1995). Hands-on models help students to construct tactile experiences with models that are otherwise abstract, however with analogical models the is a double edged sword in that analogies may interfere with the scientific concept (Harrison & Treagust, 2000). However, they have become indispensable for teaching and learning science because they stimulate students' curiosity and imagination and verbal descriptions for complex phenomena can be overwhelming for young students. Hands-on activities and manipulative encourage students' creative thinking and allow students to understand scientific phenomena that they can not see (Harrison & Treagust, 2000). And hands-on learning also develops more positive attitudes about science and results in students becoming highly engaged and interested in science topics (John, Andre, Kubasko, Bokinsky, Treatter, Negishi, Taylor, & Superfine, 2004).

**5. Visuospatial Thinking**

Chemistry is a visual science. Chemical representations such as atomic models are partially schematized and partially iconic diagram that depict abstract concepts and apply conventions to illustrate both component and organization. The relationship between visual displays and chemistry concepts is very strong. A series of studies emphasize the role of visuospatial thinking by investigating the correlation between spatial abilities and chemistry learning (Wu and Shah (2004). There were explicitly many chemistry problems require visuospatial abilities to answer the questions, not only visuospatial problems but also non-spatial problem e.g. stoichiometry problems. Using chemical representations to perform tasks requires a series of cognitive operations in spatial domain thus it is likely that chemistry learning involves student visuospatial thinking.

There is some variation in the meaning of term used in the literature on visuospatial (also spelled visual spatial) thinking. Visuospatial thinking (or cognitive, or intelligence) used for the mental visual image within memory and higher level cognition, includes (1) vision-using the eyes to identify, locate, and think about objects and ourselves in the world, and (2) imagery-the formation, inspection, transformation, and maintenance of image in the "mind's eyes" in the absence of a visual stimulus (Mathewson, 1999). Kali and Orion defined spatial abilities include the following characteristic categories (1) the ability to recognize and comprehend the relation ships between the various parts of a configuration and one's own position. (2) the ability to generate an image and operate various mental manipulations on this image.

Psychometric test of spatial abilities vary in the underlying skills they might me measuring. Most of the studies focused on three spatial ability factors: spatial visualization, closure flexibility, and spatial relations. (Wu and Shah, 2004) Spatial visualization involves the reflect processes of apprehending, encoding, and mentally manipulating spatial form. The research studies for example rotation of one three-dimensional figure, infer the type of transformation, and properties differentiation between them (Enochsson et al., 2004; Hegarty, 2004; Wu and Shah, 2004). Mental manipulation of spatial visualization required chemistry problem solving. For example, to determine whether dibromomethane ($CH_2Br_2$) is a polar molecule, students need draw or show a schematized two-dimensional structure formula. However, the two diagrams could lead to different conclusions unless students mentally or physically create a three-dimensional of the molecule to indicate the dibromomenthane is a polar molecule because the two polar bonds between Carbon and Bromine do not lie along the same axis in three-dimensional space as Figure 2.1.

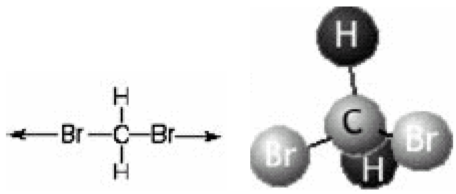



**Figure 2.1** Two-dimensional and three-dimensional representation of $CH_2Br_2$

Closure flexibility is concerned with the speed if apprehending and identifying a visual pattern, often the presence of distracting stimuli. Closure flexibility requires internally maintaining a given pattern and contracting the distracting stimuli. Tasks used for measured closure flexibility such as find a shape-puzzle in which people must find simple figures embedded in more complex ones (Kali and Orion, 1996; Schlooz et al., 2006; Wu and Shah, 2004). This factor is also considered related to chemical problem solving for example the chemical equation in Figure 2.2 which need considering which reagents (b) needed to produce compound NaKP by using compound NaOH as a reactant. Students need to identify visual similarities and differences disappeared of the two molecular structure and find out the possible molecule X bases on the information.

$$NaOH + X \longrightarrow NaKP + H_2O$$

**Figure 2.2** A chemical equation for synthesis Sodium potassium phosphate

The last factor is spatial relations. Spatial relations are similar to spatial visualization in that requires mental transformations, but different in that they involve simpler manipulations, usually within single step, of two-dimensional objects and tend to emphasize speed. The research study regards this factor of visuospatial ability for example card rotation test which needs considering the figure similar to the target figure of Barnea and Dori (1996). Chemistry problem requires this visuospatial ability, relates to the identification of isomer for example Figure 2.3., whether molecule A and B are geometric isomer.


**Figure 2.3** The two displays of 1-Chloropropane

Students have to mentally rotate the single bond between the two Carbon atoms to indicate they do not isomer but represent the same structure.

# CHAPTER III

# RESEARCH METHODOLOGY

The intention of this chapter is to present the research methodology and methods used in the study. Describe design, construction, and selection of instructional materials. Describe the data collection and the data analysis method.

## Theoretical Perspective

This research relies on qualitative research, uses interpretivism as a theoretical framework (Neuman, 2003) to describe participants and situation occur during data collection. This research designs to investigate the effect of instructional units through teachers and students. How do chemistry teachers implementation chemistry curriculum. How do students learn chemistry concepts from the chemistry curriculum, and how do they understand those chemistry concepts.

### 1. Interpretivism

Interpretive study concerned relativist and shared understanding of phenomena, intent to gain a deeper understanding of the phenomena which is believed can be used to inform in other contexts (Neuman, 2003). Interpretive researchers attempt to understand the way research subjects construe, conceptualize, and understand events, concepts and categories as these are assumed to influence individual behavior (Schwandt, 1994; Williams, 2000). They assume that knowledge and meaning are acts of interpretation hence there is no objective knowledge which is independent of thinking, reasoning humans. The central all of these has been a concern with subjective meanings, how individuals or members of society apprehend, understand and make sense of social events and settings (Schwandt, 1994) and how this sensemaking produces features of the very settings to which sensemaking is responsive (Gallagher, 1991). Given the concern with understanding members' meanings, interpretive researchers have often preferred meaning oriented methods. In particular, data collection and representation have been accomplished with informant interviewing (Spradley, 1979), ethnography, or the thick description of cultures based on intimate knowledge and participation (Van Maanen, 1988, Gallagher, 1991), and even ethnographically linked textual analyses which use transcripts or verbal protocols of meetings as data. Such verbal or conversational data are collected to represent interactions in important, naturally occurring social settings without value in the context of justification (Schwandt, 1994).

Interpretive research allowed to study and understanding of science classroom as socially and culturally constructed environment for learning, the nature of teaching as feature of learning environment, and the way in which teachers and students make sense of and give meaning to their interactions as the central element of the educational process (Gallagher, 1991). This approach of research permit to learn about the thinking, belief, and values of science teachers and others both within and outside the educational community who influence the environmental in which science teacher work (Gallagher, 1991). Interpretive researcher is seeking to learn how the teachers being studied see their world through their own eyes. Interpretive research permits to construct explicit cultural knowledge about science teaching and teachers that may be held outside their conscious awareness. Interpretive research not only help researchers learn about teachers' thoughts, beliefs and values, but it illuminates them for the teachers themselves, thus allowing teachers to become more reflective about their own work. The work of the interpretive researchers is to understand and workings of social interaction within classroom, study the social nature of science teaching. Interpretive research has a central concern with the ways that persons make sense, and giving meaning to, the social interactions that constitute daily life in and around schooling, especially the discourse between teachers and students that influences understanding of subject matter.

Interpretivism and positivism are contrasting (Gallagher, 1991; Neuman, 2003). A positivism researchers will precisely measure selected quantitative details about thousands of people and used statistics, where and interpretive researchers may live a year with a dozen people to gather a large quantity of detail qualitative data acquire an in depth understanding of how they create meaning in everyday life. Positivism's instruments orientation and the interpretive approach adopts a practical orientation are also different. Interpretive approach concerned with how ordinary people manage their practical affairs life, or how they get things done, how people interact and get along with each other. In general, the interpretive approach is the systematic analysis of social meaningful action through the direct detailed observation of people in nature settings in order to arrive at understandings and interpretations of how people create and maintain their social worlds. In the point of generalizability, positivist researchers presume that we can generalize from the past to present and future events. In an effort to use research to improve teaching, they see a job of teachers as that of teaching for general characteristic of effective teacher, it is presumed that other teachers should be able to learns these techniques and apply them into their classroom. In interpretive research, by contrast, effective teaching is not seen as a set if generalized attributes of teacher or students. Rather, effective teaching is seen as occurring in particular and concrete circumstances of practice of specific teacher with a specific set of students (Gallagher, 1991). So interpretive research is study specific classroom in isolation and interested in relationship between theses specific classroom and the large social organization and culture which influence the activities of teachers and students in making choices and conducting their daily work. Interpretive researchers are interested in understanding the specific detail of interactions that constitute effective teaching and learning which occur between teachers and students, as well as, among students, and with the world outside. Positivist research seeks to find and give teachers new tools and techniques for doing their job better. By contrast, interpretive research seeks to improve teaching by helping teachers (and researchers) better understand the nature of their work and the meaning they give to it. The very important point of the different between positivist research and interpretive research is a difference in view about causality. Positivist research try to understand a linear causality, task of researchers is viewed as establishing the social fact that determines the behavior under study. In interpretive research, causality is viewed in a more dynamic, interactive manner. The object of interpretive research is action not behavior. Effective teaching so based on what teachers and students do together in the dynamic interaction that constitutes the science classroom, interpersonal interactions among students, and interpersonal interactions between students and the teacher within and beyond the class.

The primary analytic methods used in interpretive research are grounded theorizing and expansion analysis. The basis of grounded theorizing is the idea that positivism is oriented to testing and confirmation of general theories which take the form of well validated propositions which specify relations, often causal, among well defined and quantitatively measured variables. The result is that positivism is effective for theory testing but it precludes theory development and discovery because positivist methods are inherently oriented to testing pre-established hypotheses and propositions. Grounded theory was developed to encourage the development of low level or grounded theories to represent the patterns surfaced in low level or setting specific field research, a mid-range level of theory which was ignored in grand social theorizing (Glaser and Strauss, 1967). It also sought to attempt to ground or use these highly abstract theories or concepts in specific contexts and research endeavors as a way of determining if the concepts or general theories did have empirical relevance and practical usefulness.

## 2. Grounded Theory

In, qualitative research, grounded theory often begins with sensitizing or orienting concepts which provide the researcher with a general sense of reference and guidance in approaching empirical instances (Bogdan and Biklen, 1998). The sensitizing ideas are examined or applied through micro level observations of interactions in specific social settings. Sensitizing concepts are thereby elaborated and further developed to capture and reflect discovered features of the phenomenon examined. Data are collected often in the form of field notes of interactions and conversations with an interest in surfacing a focus and collecting multiple examples of the phenomenon of emergent interest. Sensitizing concepts act as theoretical lenses to help the researcher find examples as well as patterns in the meanings represented in data, using theoretical sampling rather than random sampling to identify examples of research interest. Constant comparative analysis (Glaser and Strauss, 1967) provides an alternative to statistical analysis. Essentially this comparative analysis process examines all data slices which are similar on a given dimension or category and compares these to slices which are similar on one or more dimensions but differ on theoretically important dimensions. For example, all statements by workers describing their experiences of risk and danger during an accident can be collected and compared to statements by managers concerning their experiences of risk and danger. This process is used to generate theoretical properties for a category or concept of interest in contrast to other properties and categories. For example, here it could be used to understand different organizational positions (an important, prior categorization of informants) and their experiences of work as involving risk, danger, fear and a sense of safety. Constant comparative analysis is completed by 1) comparing all incidents relevant to a given theoretically meaningful category, 2) integrating the categories and their properties, 3) delimiting the range of the theory and then 4) writing the theory (Glaser and Strauss, 1967).

## Research Design

### 1. Survey Study

To study the overview of Atomic Structure and the Periodic Table Instruction in the current context the questionnaire were conducted with students in the schools with have similar context to the school cases that intended to study. The questions used in constructing the survey questionnaire are based on concepts related to learning atomic structure and the periodic table as stated in the IPST basic science curriculum: (1) atomic structure including atomic models, subatomic particles, atomic number, atomic mass and isotope, electromagnetic spectrum and electron configurations, (2) the periodic table including history of the periodic table organization, periodic trends of the elements, and chemical properties of compounds (IPST, 2003).

From finding revealed that most of the participants students were faced difficulty in leaning atomic structure and the periodic table. The highest mentioned are the topics requiring understanding (even though student's mentioned those topics are needs memorization) for example in the topics in the periodic table which mention the most difficult for students' learning is the periodic trends of element e.g. electron affinity, electronegativity, atomic size and ionic radius, ionization energy. This result congruent with students' mentioned, they got problems in topics learning atomic structure e.g. atomic model and electron configuration of the elements which are prerequisite for understanding periodic trends of the elements. Because of the periodicity of the elements related to their electron configurations. The quantitative computation is also the problem for students in learning atomic structure and the periodic table for example the calculation on the electromagnetic spectra, isotopes, atomic, number, mass number, atomic mass etc. In addition the language use in chemistry is also a problem for students' learning e.g. mass number and atomic mass, to students these terms is the same thing. In fact they are different, mass number is the number of protons plus neutron of an isotope of the element in the other atomic mass is the average mass of every isotope found in nature of the element. You may see here why students indicated that the topics in atomic structure and the periodic table is confused them.

The learning format students' used for learning atomic structure and the periodic table are all traditional methods such as lecture and worksheet. However the learning formats that students indicated prefer to use still include these traditional ways, especially lecture is still indicated in high percentage. We may infer that even we use innovative ways in teaching, the traditional lecture is also important for instruction. Even though lecture is not a scientific ways to investigate knowledge in science but teachers may use it as a guide for students' inquiry and make a summarization of what students had discovers to help them link the new knowledge to the related science topics they have learned or will learn further.

The learning format hat students most prefer to use in their learning atomic structure and the periodic table is computer visualization. As we know that children world in this day relies on compute. Numeral students rather spent time for computer than books or paper works. They play online games or chat over msn/icq with friends (over the world). According to students prefer activities and learning styles the atomic structure animation/game and the interactive periodic table probably more interesting for students to learn this contents. And of course the best source and easiest way for exploring knowledge and information is using internet. The condition of learning has changed if teachers use this change to support their teaching. This may lead the instruction to student center as we wish and students will be happier to learn science.

The data revealed form this research study may help teachers rethinking what is the best for students' learning. Teachers could use this data in designing benefit atomic structure and the periodic table lessons. As the data shown students stated their learning heavily based on memorizing, to help them understand the concepts of these topics, not rote learning, the historical perspective of teaching could be help to solve the problem. Since the knowledge development in atomic structure and the periodic table occur in time line and scientist used the previous discovers helped constructing their own knowledge. This historical perspective of teaching not only provides students picture the ways of knowledge development but also reveal them the nature of science which knowledge can be change if the new knowledge explain the phenomena better, e.g. scientist no longer use Thomson's atomic model to explain phenomena occur in atoms. Another thing is show students the relationship between topics, emphasize them that there is no independence topic in the atomic structure and the periodic table, especially students really need to understand atomic structure, electron configurations to understand phenomena of periodic trends of the elements. Some topics in atomic structure and the periodic table require quantitative calculation. Teachers should find out students' prior knowledge in mathematics before teaching the topics to help students' better understanding. Innovative using computer in the instruction is prominent; teachers could not ignore this because the environment of students has changed. The computer visualization may help encourage students interesting and better understanding the topics as they stated that they prefer learning using computer visualization.

## 2. Pilot Study

The pilot study was conducted on August 12-October 12, 2005 with 2 classes of Apalachee High School students, Grade 11, in fundamental chemistry course. The first class was 25 students and the second class was 23 students. There was 90 minute chemistry class and 5 days per weeks, Monday-Friday. The researcher taught all of those classes.

The data revealed that student like the video clips and the VAST-models. They mentioned that both video clips and the VAST-models is helpful in their learning about atomic structure and the periodic table. The following is an example of student reflection about the instructional units on the questionnaire.

> “The video clips were a great thing to have within a lesson. They really helped to visuallize some of the experiments structures, etc. of the periodic table and of the atomic structure”

> “I love the 3D models. They helped a lot. I think I learn better visually, instead of just hearing it!”

The data from student's concept map shown that the instructional units helped students in learning atomic structure and the periodic table. This is an example of students' concept map. The data from test showed that 78% of students got high score and not much students (3%) did not pass the tests. The data from interview is shown that the video clips make in lessons more interesting and dynamic. Anyway after interviewed the researcher found that students didn't focus on the right point of the video clips. So the researcher adds questions into the power point slide to scope student's idea. The result form using the VAST-models was very good. Students can use the VAST-models to explain concepts in atomic structure and the periodic table this shown students were understand well in the concepts in atomic structure and the periodic table. They said that they like the VAST-models because they can play with it. Moreover when the researcher asked them to compare the VAST-models with the picture of the quantum mechanical model in the figure 1 that come from their chemistry textbook, they said that the atomic model in the picture didn’t make sense to them but they understand quantum mechanical model by the VAST-models better. However the researcher found that students did not work well on transfer the Bohr's model to the quantum mechanical model. They do not know where are the atomic orbitals (quantum mechanical model) in the energy levels (Bohr's model).

All of data found in the pilot study was used to improve the instructional units as following.

- Ask questions before and after present the video clips.

- Relate quantum mechanical model to Bohr's model by put atomic orbitals on the energy level of Bohr's model.

- Edit the power point slides: content

- Write the chemistry textbook by using the timeline and add the history and philosophy behind chemist's study.

- Improve activities (work sheets); wording, feature, adjust time.

## 3. Design, Construction, and Selection the Atomic Structure and the Periodic Table Instruction Units (ASPTUs)

### 3.1 Level Standard for Grade 10-12 Chemistry Learning

The ASPTUs was developed for teaching chemistry in level 4 (Grade 10-12). The instructional units were based on the National science curriculum of Thailand (IPST curriculum). There are two Sub- strands which are relevant; Sub-strand 3 and Sub-strand 8.

The Institute for the Promotion of Teaching Science and Technology (IPST) is the organization responsible for developing the curriculum in Thailand. IPST also sets the standards for teachers and students and provides core subject matter for basic education in Grades 1-12. IPST provides learning units, descriptions of the basic science courses, and lesson plans. The IPST chemistry curriculum is divided into four levels; Grades 1- 3, Grade 4-6, Grade 7-9, and Grade 10-12. Each standard shares themes running from simple to more complex concepts for the different grades. Participants will explore and share opinions in comparing the 8 principal sub stands in IPST curriculum: Living Things and Living Processes, Life and Environment, Matter and Properties, Forces and Motion, Processes that Shape the Earth, Astronomy and Space, and Nature of Science and Technology.

#### 3.1.1 Sub-strand 3: Matter and Properties

**Standard Sc. 3.1:** The student should be able to understand properties of matters, relationship between properties and structure and forces among particle, have skill in investigative processes and possess a scientific mind, communicate acquired knowledge and make positive application of knowledge.

#### 3.1.2 Sub-strand 8: Nature of Science and Technology

**Standard Sc. 8.1:** The student should be able to use the scientific process and scientific mind in investigation, solving problems, know that most natural phenomena have definite patterns explainable and verifiable within the limitations of data and instrumentation during the period of investigation, understand that science, technology and environment are interrelated.

#### 3.1.3 Level Standard for Grade 10-12

1) Level Standard for Grade 10-12 of Sub-strand 3

– Search for information, discuss, and explain the structure of the atom, kinds, and numbers of elementary particles in the atom from nuclear symbols of elements, analyze and compare electrons in the outermost shell for their manifestation in terms of properties of the elements and their reactions.

– Investigate and analyze data on the properties, compounds, and atomic number of elements, explain the arrangement of elements on the Periodic Table and predict trends of their properties according to their positions on the Table.

2) Level Standard for Grade 10-12 of Sub-strand 8

– Pose questions based on knowledge and understanding of science or personal interest or issues arising which are subject to investigation or experimentation in a comprehensive way and with great confidence.

– Set up hypothesis which is supported by theory or which predicts findings or set up models or schemes for investigation.

– Choose material, technique, apparatuses for investigation, observation and measurement for both qualitative and quantitative data.

– Collect data and record result from investigation systematically, correctly and comprehensively both in qualitative and quantitative terms, while checking for probability, appropriateness or defects in data.

– Analyze data, interpret data and evaluate correlation with conclusion or essential issues to check the proposed hypothesis.

– Make models or pattern representations or mathematical models or point out trends of data gathered from investigation.

– Scrutinize reliability of methods and results from investigation based on errors in principles measurement and observation and propose improvements on method of investigation.

– Bring methods and new knowledge from investigation to bear on new questions, solve new problems in new situations in real life.

– Realize the importance of shared responsibility in explaining, expressing opinions and concluding for the scientifically correct presentation to the public.

– Record and explain with reasons results from investigation using referenced and researched evidence to obtain reliable support and concede readily that knowledge is subjected to change when new data and additional evidence crop up to challenge or oppose old views giving rise to the need of careful checking and perhaps to acceptance new knowledge.

– Prepare presentations, write report and/or explain concepts, or processes and results from the project or work to others.

### 3.2 The Design of the Instructional Units

The ASPTUs was developed to entrance student understanding and visuospatial thinking for concepts in atomic structure and the periodic table. The finding of situation of atomic structure and the periodic table instruction which was mentioned above informed the selection of activities and video animations, as well as, the construction of the VAST-models. The selected activities and visuospatial was based on the purposes of teaching and learning atomic structure and the periodic table in the IPST curriculum.

The review of the ASPTUs was based feedback from three volunteer teacher and scientist and science educators who validated the concepts, learning activities, visuospatial models, and the assessment for each unit. Moreover, the volunteer teachers also helped adapt the instructional unit for the context of their students and classroom situation.

### 3.2.1 The Selected Activities

1) Activities of Atomic Structure

- Mystery Boxes
- 125 Questions: What don't we know?
- What do you think?
- How far away is the electron?
- Relating Electron and Probability
- What did they do?
- Atomic Structure
- VAST-models and Structure of the Elements
- Isotope
- The Atomic Mass of Candium
- Lab: Flame Tests
- Atomic Spectra
- Electron Configuration

2) Activities of the Periodic Table

- Where is their home?
- Who am I?
- Who is it?
- Metals and Nonmetals
- Metalloids
- Transition Metals
- Metals, Nonmetals, and Metalloids
- The Universal Periodic Table
- The Importance of Metals
- Elementary Facts

- Periodic Table Puzzle
- How can chemists determine atomic radii?
- Periodic Trend in Ionic Radii
- Calculating Oxidation Number

### 3.2.2 The Selected Video Animation

There are 13 video clips, 10 video clips for content in atomic structure and 3 video clips for content in the periodic table. The video clips in atomic structure is including Thomson's experiment, Milligan's experiment, Rutherford's experiment, states of electron according to Bohr's atomic model, atomic line spectrum of exited Hydrogen atom, atomic model, electron cloud, wave properties of electron, electron spin, and Hydrogen's subshell energy. In the periodic table including video clips for first ionization energy of Magnesium, second ionization energy of Magnesium, and electron affinity of chlorine. All of video clips are inserted in the power point presentation. Before and after using video clips, students will be asked questions for scope students' idea and gather students go to the point. The data from pilot study of the atomic structure and the periodic table instructional units with Apalachee high school students is shown that video clips with questions make students ready to learn from video clip. The following are scripts of the video clips.

1) Thomson's Experiment

"A cathode ray can be deflected by an electric field. The beam is attracted to the positively charge plate".

"The beam is also deflected by a magnetic field. For the experiment we orient the magnet perpendicular to the electrodes".

"The forces can be used to cancel each other. J.J Thomson used similar experiments to determine the charge to mass ratio of electrons".

2) Milligan's Experiment

"In Millikan's experiment, tiny oil droplets were spayed into a chamber. By adjusting the charge on a pair of electrodes, Milligan balanced the force of gravity pulling the droplets downward with the electric attraction pulling the droplets upward".

3) Rutherford's Experiment

"In the Rutherford experiment, gold foil was bombarded by a beam of positively charged alpha particles. Most pass straight through, some however deflected at large angles, but with a few coming almost straight back".

"The particles were deflected by a high positive charge in a very small volume, the atomic nucleus".

4) States of Electron According to Bohr's Atomic Model

"According to the Bohr model, when a hydrogen atom receives energy, its electron leaps from a low energy orbit to a higher one forming an excited state. As the atom loses energy, the electron jumps back to a lower energy orbit, releasing light as it goes. When gaining energy the orbit to which the electron jumps depends on the amount of energy involved. When the electron occupies the lowest energy orbit possible, the atom is said to be in the ground state".

5) Atomic Line Spectrum of Exited Hydrogen Atom, Atomic Model

"If a high voltage is applied to an element in the gas phase, the element emits light. Using a prism, we can split the light into its component colors. Every element emits a distinct set of colors unique to that element".

6) Atomic Model

"A familiar depiction of the atom shows electrons orbiting the nucleus like planets around the sun. This model is neither accurate nor useful. We no longer think of electrons as orbiting the nucleus and we can not predict the location which accuracy. A more useful model is the quantum mechanical view of the atom, which represents the positions of electrons in terms of their probability of being in a particular region around the nucleus. If we could show all positions for an electron with a specific quantized energy, the resulting picture would look something like a cloud".

7) Electron Cloud

This video clips present the density of electron and the movement of electrons in the cloud. However there is no verbal description.

8) Wave Properties of Electron

This video clip represents the wave properties of electron. There is no verbal description in this video.

9) Electron Spin

"Any spinning electric charge creates a magnetic field. Spinning electrons produce magnetic fields with an identifiable magnetic polar orientation, so called North or South. The polar orientation of a given electron is determined by the direction of its spin".

10) Hydrogen's Subshell Energies

"A single electron atom, hydrogen, subshell energies depend only on the subshell’s principle quantum numbers. In a many electron atom, the presence of electrons in one subshell, affects the energy of other subshells, consequently the subshells are not filled simply on the base of the principal quantum numbers".

11) First Ionization Energy of Magnesium

"To remove the outer most electron from a magnesium atom, requires 738 kJ of energy per mole".

12) Second Ionization Energy of Magnesium

"Removing the second electron require more energy, 1451 kJ/mol".

13) Electron Affinity

"When a gaseous atom accepts an electron to become an anion, the energy it releases is a measure of its electron affinity. For chlorine, this is -349.0 kJ/mol".

### 3.2.3 The VAST-models (Visualizing Atomic Structure through Models)

VAST-models were developed based on the assumption that scientific practice is discipline specific, that chemistry instruction should be designed around key models, and that teachers and students should be able to work with and experience multiple representations for chemistry phenomena including constructing, using, revising, and critiquing models for their usefulness. Furthermore, students should be able to experience the historical development of the ideas for atomic structure in the context of the time that they each model was proposed and evaluate each for its usefulness and contribution to our understanding concepts for atomic structure and the periodic table.

VAST-models are 3D visual representations that can be used for teaching and learning atomic structure and the periodic table, including quantum number and orbitals, atomic number, atomic mass, isotope, electron configuration, valence electrons and the positions (groups and periods) of the first 20 elements in the periodic table through inquiry. The models include two sets of materials, one set is for teacher demonstrations (Figure 3.1) and the second set is for students' hands-on/minds-on inquiry activities (Figure 3.2).

The atomic model as a quantum mechanical model estimates the probability of finding an electron in a certain position or place, Heisenberg's uncertainty principle. If we could show all positions for an electron with a specific quantized energy, the resulting picture would look something like a cloud and the VAST-models are used to represent this electron cloud in the atom of elements.

Greek Dalton Thomson Bohr Quantum

**Figure 3.1** VAST-models for teacher demonstrations

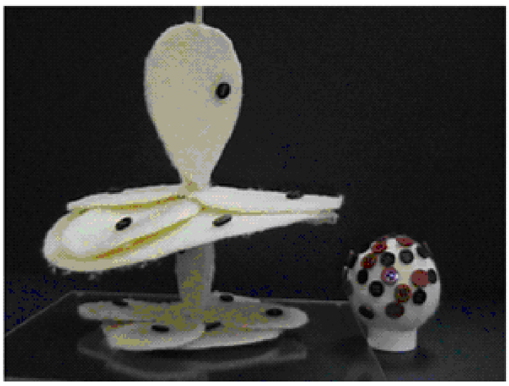


**Figure 3.2** VAST-models for students' hands-on learning.

### 3.3 The Structure of the Instructional Units

A summary of the atomic structure and the periodic table instructional units included activities and assessments for each unit are presented in the table.

**Table 3.1** Outline of atomic structure and the periodic table instructional units

| Units | Concepts | Activities | Materials | Assessments |
|---|---|---|---|---|
| 1. The use of models in science.<br>(2 periods/100 mins) | 1. Scientists have many strategies which allow them to infer, construct or make tentative conclusions based on their indirect observations. Scientists usually rely on past experiences to help them make inferences. Many times scientists share information or work in groups to help support conclusions. | **Introduction**<br>1. Read article "125 Questions: What don't we know? Choose questions related to chemistry which student would like to find the answer and discuss.<br>**Teaching**<br>2. Group work activity on the activity "Mystery Boxes".<br>**Summarization**<br>3. Communicate the experimental result.<br>4. Relate the experimental with the ways scientists find out scientific knowledge. | 1. Worksheet 1: 125 Questions, What don't we know?<br>2. Worksheet 2: Mystery Boxes.<br>3. Mystery boxes. | 1. Students' response-discussion and presentation.<br>2. Do experiment.<br>3. Group working.<br>4. Worksheets. |
| 2. Historical study of atomic structure, sub atomic particles and properties.<br>(2 periods/100 mins) | 1. Democritus proposes the word "atom".<br>2. Dalton proposed atomic theory.<br>3. Thomson found the negative electron and e/m ratio of electron.<br>4. Goldstein found the positive proton.<br>5. Chadwick found the neutral neutron.<br>6. Rutherford found atomic nucleus.<br>7. Bohr proposed electron energy level.<br>8. Schrödinger proposed quantum mechanical model of atom. | **Introduction**<br>1. Survey students' prior knowledge about element, atom, electron, proton, neutron by do worksheet "What do you think?"<br>**Teaching**<br>2. Present video animations about the experiments of scientists and discuss.<br>3. Group work activity "Relating Electrons and Probability".<br>4. Demonstrate atomic models using VAST-models.<br>**Summarization**<br>5. Discuss worksheet "What did they do?" | 1. Worksheet 1: What do you think?<br>2. Worksheet 2: What did they do?<br>3. Video animations.<br>4. VAST-models | 1. Students' response-discussion and presentation.<br>2. Worksheets.<br>3. Concept mapping. |

**Table 3.1** (Continued)

| Units | Concepts | Activities | Materials | Assessments |
|---|---|---|---|---|
| 3. Nuclear symbol, atomic number, mass number, isotopes, atomic mass.<br>(2 periods/100 mins) | 1. Nuclear symbol, the symbol for an atom, $^{A}_{Z}X$ , $X$ is symbol for an element, Z is its atomic number and A is its mass number.<br>2. Atomic number is the number of protons in the nucleus of an atom.<br>3. Mass number is the integral sum of the numbers of protons and neutrons in an atom.<br>4. Isotopes are two or more forms of atoms of the same elements with different masses.<br>5. Atomic mass is weight average of the constitute isotopes of an element. | **Introduction**<br>1. Inquire students' understanding of atomic structure using part A in worksheet "Atomic Structure".<br>**Teaching**<br>2. Use VAST-models to determine atomic number, mass number, and isotopes using worksheet "Exploring VAST-models for the Atomic Structure of Elements".<br>3. Do an experiment "The Atomic Mass of Candium", communicate and discuss the experiment result.<br>4. Perform calculation of atomic mass.<br>**Summarization**<br>5. Discuss part B in worksheet "Atomic Structure". | 1. Worksheet 1: Atomic Structure.<br>2. VAST-models<br>3. Experiment "The Atomic Mass of Candium". | 1. Students' response-discussion and presentation.<br>2. Do experiment.<br>3. Group working.<br>4. Worksheets.<br>5. Concept mapping. |
| 4. Wave properties and electro-rnagnetic radiation of atomic spectra<br>(3 periods/150 mins) | 1. Electrornagnetic radiation is propagated by means of electric and magnetic fields.<br>2. Spectrum is a display of component wavelengths of electromagnetic radiation.<br>3. Emission energy or photon equals h$\nu$, h=Planck 's constant, 6.626 X $10^{-34}$ J.s. and $\nu$ is frequency. | **Introduction**<br>1. Find out students' existing about electromagnetic spectrum e.g. light and component of wave by posting questions.<br>**Teaching**<br>2. Do an experiment "Flame Tests", communicated and discuss the experiment result.<br>3. Do worksheet "Atomic Spectra"<br>4. Perform calculation of wave properties and photon energy. | 1. Worksheet 1: Atomic Spectra.<br>2. Experiment "Flame Tests".<br>3. Reading paper "Lighting and Light Bulb" | 1. Students' response-discussion and presentation.<br>2. Do experiment.<br>3. Group working.<br>4. Worksheets.<br>5. Concept mapping. |

**Table 3.1** (Continued)

| Units | Concepts | Activities | Materials | Assessments |
|---|---|---|---|---|
| 4. (Continued) | | **Summarization**<br>5. Discuss on the phenomena of gases atoms in light bulb, relate light spectra and atomic spectrum of elements. | | |
| 5. Quantum numbers and atomic orbitals. (1 periods/50mins) | 1. There are 4 quantum numbers; principle quantum number (n) describes the main energy level, angular momentum quantum number ($l$ ) describes shape of the region which electrons occupy (orbitals), magnetic quantum number ($m_l$) refers to the spin of electron and orientation of the magnetic field produced by this spin. | **Introduction**<br>1. Explore students' existing knowledge about Bohr's and Schrödinger's atomic models.<br>**Teaching**<br>2. Do activity "Quantum Numbers and VAST-models".<br>3. Perform calculation of quantum numbers.<br>4. Demonstrate shapes and positions of atomic orbitals in atomic structure using VAST-models.<br>**Summarization**<br>5. Discuss of electron energy level and atomic orbitals in VAST-models. | 1. Worksheet 1: Quantum Numbers and VAST-models.<br>2. VAST-models. | 1. Students' response and discussion<br>2. Group working.<br>3. Worksheets.<br>4. Concept mapping. |
| 6. Electron Configuration. (1 periods/50mins) | 1. Electron configuration is the specific distribution and ways in which electrons are arranged in atomic orbitals around the nucleus of an atom. Electrons will enter orbitals of lowest energy first (Aufbau principal), | **Introduction**<br>1. Explore students' existing knowledge about Schrödinger's atomic model, quantum energy, and atomic orbitals. | 1. Worksheet 1: Electron Configuration.<br>2. VAST-models. | 1. Students' response and discussion<br>2. Do experiment.<br>3. Group working.<br>4. Worksheets.<br>5. Concept mapping. |

**Table 3.1** (Continued)

| Units | Concepts | Activities | Materials | Assessments |
|---|---|---|---|---|
| 6. (Continued) | at most two electrons are in an atomic orbital (Pauli exclusion principal), and when electrons occupy orbitals of equal energy, one electron enters each orbital until all the orbitals contain one electron with pararel spin (Hund's rule). | **Teaching**<br>2. Use VAST-models demonstrate and explain electron configuration.<br>3. Perform electron configuration using VAST-models.<br>**Summarization**<br>**4.** Discuss on worksheet "Electron Configuration". | | |
| 7. Historical study of the periodic table, and the periodic table and electron configurations. (2 periods/100 mins) | 1. Mendeleev used order of atomic mass to arrangement elements in pattern.<br>2. Moseley found there was better arrange elements by increasing atomic number based on the nuclear charge.<br>3. Predict position of elements in the periodic table using electron configuration outer most electron energy level represent "period", valance electrons represent "group". | **Introduction**<br>1. Review students' understanding of concept of electron configuration.<br>**Teaching**<br>2. Discuss the discovery of scientists about the periodic table.<br>3. Perform arrange elements into the periodic table, do worksheet "Where is their home?"<br>4. Discuss an overview physical and chemical properties of Metals and Nonmetals, Metalloids, and Transition Metals using worksheets.<br>**Summarization**<br>5. Discuss how related the position of an element and its electron configuration. | 1. Worksheet 1: Where is their home?<br>2. Worksheet 2: Metals and Nonmetals.<br>3. Worksheet 3: Metalloids.<br>4. Worksheet 4: Transition Metals.<br>5. Worksheet 5: Who is it? | 1. Students' response and discussion<br>2. Worksheets.<br>3. Concept mapping. |

**Table 3.1** (Continued)

| Units | Concepts | Activities | Materials | Assessments |
|---|---|---|---|---|
| 8. Chemical periodicity of the elements (2 periods/100 mins) | 1. Atomic radii is a size of atom, often stated in angstrom (1 $A^0 = 10^{-10}$m).<br>2. Ionization energy is amount of energy required to remove electrons from atom.<br>3. Electron affinity is amount of energy absorbed when electron is added to an isolate gaseous atom to form anion (a 1-charge).<br>4. Ionic radii is ion size, cation is smaller, anion is bigger; compared to atom of the element.<br>5. Electronegativity is a measure of relative tendency of an atom to attract electrons to itself.<br>6. Melting point and boiling point and the energy required for change state of elements.<br>7. Oxidation number of an element in simple binary ionic compound is the number of electron gained or lost by an atom of that element when it forms the compound. | **Introduction**<br>1. Explore students' prior knowledge using worksheet "Periodic Puzzle".<br>**Teaching**<br>2. Do experiment "How can chemists determine atomic radii"<br>3. Discuss the chemical periodicity of the elements.<br>4. Perform calculation of an oxidation number.<br>**Summarization**<br>5. Discuss the trends of atomic radii, ionization energy, ionic radii, electronegativity, electron affinity, melting point and boiling point, and oxidation number. | 1. Worksheet 1: Periodic Puzzle.<br>2. Worksheet 2: Oxidation Number.<br>3. Experiment "How can chemists determine atomic radii?" | 1. Students' response discussion and presentation.<br>2. Do experiment.<br>3. Group working.<br>4. Worksheets.<br>5. Concept mapping. |

## 4. School Case Study

### 4.1 School A

School A was established in 1932 on the requirement to wet up a girl school in Nonthaburi province. The school was named "The girl school of Nonthaburi province". School A covers teaching from Grad 7 to Grade 12. The school is a large size school with 2,935 students and 136 teachers. There are 10 classes in Grades 7-9 with 44-45 students in each class. From Grade 10-12 are 12 classes and 40-50 students in each class. The classes in Grades 10-12 are separated into three programs which three classes in the mathematics and science program, two classes in the social and mathematics program and four classes in the social and language program. Students in the three classes in the mathematics and science program were put in a class using GPA (Grade Point Average) from Grades 7-9. There are 17 science teachers, the three of them are chemistry teachers. One of the three chemistry teacher teach chemistry for all classes in Grade 10, the other one teach chemistry for all classes in Grade 11, and the rest chemistry teacher teach chemistry for all classes in Grade 12.

#### 4.1.1 Teacher (Jandra)

Jandra (a pseudonym) graduated diploma degree in education with a major in chemistry, bachelor's degree in education with a major in chemistry, and master degree in environment science. After graduate bachelor's degree she taught general science for seventeen years. She started teaching chemistry in 1995 which means she has 12 years experiences in high school chemistry teaching at the time of the study. Jandra did not believe in student center, she stated that;

> "…When we were young, teaching strategy was not many. Teachers used only chalk and talking, however it made us understand and still remember concepts until

> now. But nowadays we have many teaching strategies, but I don't know how much students learn".

Jandra taught atomic structure and the periodic table according to IPST curriculum. She taught every concept mention in IPST's chemistry textbook and doing activities which suggest by IPST. She tied to do every experiments mentioned in IPST curriculum, however, she hoped this group of chemistry students will more like to do activities. In this semester, Jandra teach chemistry in Grade 10 for six periods a week, and she has another six teaching periods per in biology. Jandra has no extra works in a semester of the study.

#### 4.1.2 Students

The students are a class in mathematics and science program at Grade 10. There are 44 students in this class, all of them are girls. The students were aged 14-16 years old. They were all held GPA more than 3.00 from their Grades 7-9. This could be inferred that students in this class should have high ability in chemistry. However, Jandra suggested the high GPA does not mean students have strong science content (teach Grade 7-9 general science). Students may have high grade in other subject not science.

### 4.2 School B

School B was established in 1898 by Prakru Dej, the abbot of the Buddhist temple, Wat Tan Muang and Praya Siam Nontha Ket Kayan, the administrative assistant of Nonthaburi province at that time. At the beginning school B was teaching at primary level. In 1924 school B was extend to high school. Now school B is teaching only Grades 7-12, as a large size school with 2,658 students and 117 teachers. There are 12 classes in Grades 7-9 with 45-55 students in a class and 8 classes in Grades 10-12 with 35-45 students in a class. The 8 classes in Grades 10-12 are separated into three programs which four classes in the mathematics and science program, two classes in social and mathematics program, and another two classes are in social and language program. Students in mathematic and science program were put in a class using GPA from Grades 7-9. Some of students in mathematic and science program are students in the Development and Promotion of the Gifted in Science and Technology Project (DPST) of IPST. This group of students was assigned into the mathematics and science automatically. There are 11 science teachers of which two are chemistry teachers. Among the three chemistry teachers, there were two chemistry teachers teach chemistry at Grade 10 and chemistry teacher at Grades 11-12 were also two teachers.

### 4.2.1 Teacher (Chuchart)

Chuchart (a pseudonym) graduated bachelor's degree in chemistry in the Program for Promotion Talented Science and Mathematics Teachers (TSMT) of IPST. He also graduated a diploma in chemistry teaching. Chuchart started teaching in 2006, the year after he graduated the diploma. Chuchart is a novice teacher, however he was guaranteed that he has strong chemistry content by his IPST scholarship as a whole program. Chuchart never teach atomic structure and the periodic table. Albeit, as a young blood teacher he think he is able to teach chemistry at all grade level and also he is a teacher of students in the DPST Program which means he was trained for teaching gifted students. In the semester of the study, Chuchart teach 21 periods per week, he has a special class for DPST students and he is also an advisor of DPST science project.

### 4.2.2 Students

The students were in the mathematics and science program at Grade 10. There were 42 students in class with 13 boys and 29 girls. The students were 15-16 years old. They were all held GPA in the range 2.50-3.90 from their Grade 7-9. The students in the class received different experience in science because some of the students are scholarship students in DPST program who have a chance to attain science camp or work with scientists in the university of IPST in every semester break. Moreover, these groups of students do a science project a whole year long.

However, Chuchart said there are no differentia in learning chemistry between normal and DPST students because not all students in this group have a special talent in chemistry just few of them.

### 4.3 School C

School C was established in 1900 from the idea of Prakru Silaphirom, the abbot of Wat Bang Kwang, Buddhist temple. School C covers teaching from Grade 7-12. The school is a large size school with 2,088 students and 109 teachers. There are 10 classes in Grade 7-9 with 45-50 students per class. From Grade 10-12 are 7 classes with 45-50 students in each class. The class in Grade 10-12 are separated into two programs which four classes in the mathematics and science program, and three classes in social and language program. Students in the four mathematics and science program were put in a class using GPA of Grade from Grade 7-9. There are 12 science teachers and 3 of them are chemistry teachers. Each of them responded to treat chemist at each grade level. One teacher teaches chemistry at Grade 10 and the other two chemistry teachers teach Grade 11 and Grade 12, respectively.

#### 4.3.1 Teacher (Wanarat)

Wanarat (a pseudonym) graduated bachelor's degree in Education with a major in chemistry.  The semester of the study is her first semester of full time teaching. Wanarat has 4 semesters teaching experience; two semesters in secondary school chemistry and two semesters in high school general science. She realized that atomic structure and the periodic table are very import for learning chemistry, "they serve fundamental knowledge for learning every topic in chemistry". Even though she never teach atomic structure and the periodic table , she believe it will be very interesting to teach them using visuospatial models. In the semester of the study Wanarat teach 13 periods per week, four periods for Grade 9 science project and nine periods for Grade 10 fundamental chemistry.

### 4.3.2 Students

The students were a class in mathematics and science program at Grade 10. There were 43 students in this class, 23 boys and 20 girls. The students were age 14-16 years old. They held grade average 2.50-3.80 form Grades 7-9 achievement. Wanarat mentioned that the students are moderate in learning chemistry. She felt that only few students in the class are active learners and pay attention in learning chemistry.

## Data Collection

### 1. Interview

The interview is one of the favorite methodological tools of the qualitative research. It is one of the most common and most powerful ways to understand human being. Interview has a wide variety of forms and multiplicity of uses. The most common type of interviewing is individual, face-to-face verbal interchange, but it can also take the form of face-to-face group interviewing, mailed, or self-administered questionnaire, and telephone survey. Interviewing can be structured or unstructured (Fontana and Frey, 1994). It can be used for purpose of measurement the understanding of an individual or group perspective.

Structure interviewing refers to a situation in which an interviewer asks each respondent a series of pre-established questions with a limited set of response categories. All respondents receive the same set of questions, ask the same order or sequence by an interviewer who has been trained to treat every interview situation in a like manner. Unstructured interviewing in other hand, the traditional type of unstructured interview is the open-ended in-depth interview. The interviewer-respondents interaction would be unthinkable, establish of human-to-human relation with the respondents and the desire to understand rather than to explain (Spradley, 1979). The responses are recorded by the interviewer according to a coding scheme that has already been established by the research supervisor.

In this research study, the selected interviewing was used the mixed between structured and unstructured interviewing which called semi-structured interviewing. The interviews took place with the teachers and students. The interview with the teachers was after the implementation of each unit to find out the teacher ideas of using unit, beneficial, limitation, and suggestion for using the next unit. For students, the representative students of each class were asked to interview about their learning, conceptual understanding, and perspective of the units’ implementation. All interview data was video recorded.

**2. Observation**

The observations are a primary source of information about students' learning, and informal observations take place continuously. Most teachers develop a sense of who knows what and who is having trouble with which concepts through such observations. The key to converting informal observation into assessment is to decide what student actions and behaviors will observe to assess progress here are some guidelines:

Observing how students solve problems, troubleshoot malfunctioning equipment, orb try to figure out why an experiment is successful indicates how they apply knowledge (for example, during one physical science unit in which students were building equipment, the teacher overhead students discussing which part to wiggle, pull out, and straighten). Noticing when how students relate information from text books to what they are doing in class can illuminate how they assimilate information. (In second-grade class study pollution, one student listened to a story describing bees and the used that information to correctly identify a dead bee she found on the playground). Listening to conversations and discussions can provide evidence of the appropriate use of the new vocabulary. (Similar evidence can come from labels on drawings and notebooks entries). Watching students perform a science skill reveals how well they do it and they understanding if the concepts behind it. (For example, do they begin a linear measurement at zero? Do they double check their measurements or assume that their first measurements are correct? In using a microscope, are they tilting the mirror the wrong way to catch the light? Are they focusing on the dust on the slide instead of the object?) Classroom teachers have a large number of students to observe, and a science unit usually has many learning goals. Therefore, every teacher needs some systematic way to keep track of observations, without a system, it is too easy to forget to observe important activities, too easy to over look some students.

During the units' implementation, all the classroom observations were video recorded and field noted by the researcher.

**3. Concept Mapping**

A concept map, which similar to a curriculum web, diagrams the relationships between different concepts. For example, a map starting out with the word "ocean" in the center would include as many related concepts as a students could think of: what the ocean is composed of, the living and nonliving things in the ocean and the relationships between them, how human use the ocean, and so forth. Some people claim that misconceptions are revealed both through the incorrect concept links and important links that are omitted.

While concept maps are usually used as a tool to encourage students to reflect their learning (Novok and Gowin, 1986), they can also be used for assessment. They can provide a picture of what each child thinks and knows about the topic before science units or course of study and at it end, Alternatively, a concept map can be drawn at the outset of unit a and new links can be added in other colors as the unit progresses, documenting a student's (or a class's) evolve thinking. Concept maps have been used with children of all ages, from first grade to high school.

Concept map was used for assessing students' understanding and observing what students have learn as well as how did they synthesize and construct knowledge about atomic structure and the periodic table. Students were asked to construct their own concept map, start from what do they know about electron, proton, and neutron in the worksheet "What Do You Think?". Students constructed and extended their concept map by adding their new knowledge every day after learning.

**4. Questionnaire**

Questionnaire is widely used for survey data collection. In the questionnaire structure and numerical data are provided, able respondents to administer without the present of researcher (Wilson and Mclean, 1994). There are several kinds of questions and response used in questionnaire. Dichotomous questions require yes/no response, multiple choices questions require respondents to select the provided answers in the questionnaire which a single response or several response, rank ordering questions require respondents to order the provided answer from less to most or most to less, raring scale exhausts the range of possible answer which respondents may wish to give, open-ended questions require the respondents answer in their own word.

At the end of using the instructional units all students will be surveyed by questionnaire. The questionnaire is including 2 parts, part A is about the video clips and part B is about the VAST-models. There are both ratting scale and open ended questions. The questionnaire shown in the appendix A

**5. Concept Tests**

Concept tests have been used for measuring students' understanding of concepts as they enable a large number of students to be sampled in a given amount of time as compared to time-consuming interviews. These tests are easy to administer and score, and the results obtained are also easily processed and analyzed (Tan and Treagust, 2002). Strategies such as time-management, error avoidance, checking responses and elimination of incorrect answers grammatical agreement, length of response, location of response, are needed consideration for test construction. The development of multiple-choice tests on student conceptions has the potential to make a valuable contribution to the body of work in the area of students’ conceptions, and to enable classroom teachers to more readily use the findings of research in their lessons.

The atomic structure test and the periodic table concept test were conducted at the end of each instructional unit aimed to assess student understanding of concepts in atomic structure and the periodic table. The concept test included choices, and open ended question. The choices in the concept test came from the answers which students gave in the interviews of the pilot study. The atomic structure and the periodic table concept test are shown in the appendix B and the quality of the concept test is in the appendix C.

## Data Analysis

### 1. Video Tapes of Interviews and Classroom Observations

Evidence Based Decision Support (EBDS). EBDS provides teachers with a systematic process to find, analyze, and apply critical assumptions and evidence that are used to reflect on and improve teaching practices. EBDS allows the practitioner to engage through stages of reflective analysis on identifying a trigger (assumption), collecting evidence, analyzing the evidence, and generating a course of action.

Video Analysis Tool (VAT). The Video Analysis Tool (VAT) allows teachers to remotely record and view teaching, mentoring, and learning events as they happen. Each event can be ‘chunked’ into smaller clips, and aligned with specific frameworks (e.g., GPS for Science Teaching or the NSTA Standards) through the use of a coding tool. In addition, video clips allow teaching episodes to be selected, refined, catalogued, and exchanged with peers for collaborative reflection on teaching practices.

### 1.1 Evidence Based Decision Support (EBDS)

Inquisitive and reflective teachers want to know – how am I doing? It's difficult for them to know. To understand and improve what teacher do in the classroom it takes more than global pondering (What went wrong? How did the teacher do that?) . Teachers, especially novices, may start there, but they can't resolve such broad questions. The Evidence Based Decision Support approach provides a clearly defined process for self assessment of preservice teacher's practices. Four stages of Evidence Based Decision Support include: Trigger, Evidence, Analysis, and Action. Fully, we see this as a processes teachers use across their career continuum. Each stage of the Evidence Based Decision Support process is intended to scaffold the self and/or collaborative assessment deeper into the problem, looking for evidence to explain what happened.

Trigger Stage: Something triggers teacher interests in self assessment. The trigger is caused by one of three things. Intuition - something generated from within the teacher. Teacher feels or sense something about the use of technology is not going well. *Formal Feedback* – classroom assessments, standardized tests, direct teacher observation, and other formal measures of practice and knowledge. Formative and summative assessment strategies provide powerful formal feedback. *Informal Feedback* – products students create in class. The teacher knows a strategy did not work in class, or instructional materials were not appropriate for the students. Fully, you can rely on intuition or feedback to make a statement or assumption focusing your self assessment.

Evidence Stage: Teacher begins collecting evidence to support or refute a trigger statement. There are three steps to the Evidence Stage. First, *identify* evidence most appropriate for your self assessment. Second, *collect* the evidence. Third, *organize* and prepare the evidence for analysis. Teachers only need to collect evidence that will tell you what they want to know – the attributes of practice that are successful or deficient.

Analysis Stage: Once teacher have collected the evidence will need to organize it in such way teacher cans analyze and further define that attributes of practice that are most interesting to you. Existing frameworks, especially teaching and learning standards, serve as effective organizers and descriptors for analysis. Teachers will use the National Science Teacher Association (NSTA) standards, to align expectations (expected outcomes stated as standards) and evidence extract from teaching and learning environments. The standards serve a very clear purpose in organizing your efforts, thoughts, and subsequently the evidence.

Lenses for analysis: Evidence only represents the complex event and enables you to hold it still so teacher cans look at more closely. A lens, such as the NSTA standards, helps you focus on some things while eliminating others as noise or interference. Using a camera specialty lens for shooting fall colors in the mountains, for example, can mute the green on trees and enhance the appearance of all the colorful leaves. The green is noise, its distracting and not what you are most interested, this time. The colors are vibrant and brought to the surface and become very clear even to the novice eye. Hence, want to use lenses, filters, and gradients to draw fine grained attributes of teaching practice to the surface. Classroom discipline, discussion, and presentations all become noise and interfering with the ability to focus on questioning strategies, for example, when analyzing classroom practices.

Generate Explanations: Explanations are generated by teachers individually and collaboratively through the analyses of evidence using the pre-designed lenses. In our experience teachers and observers are able to pinpoint the successful or deficient attribute of practice more effectively with the help of lenses.

Define a solution: Defining a solution is a critical point of decision making. Teacher is about to put forth effort to improve practices and grow as a teacher. Evidence-based explanations of classroom events provide a strong foundation from which to make decisions to improve. Clearly, teacher wants to know if the solution was appropriate for the need to improve.

Course of Action: The final step is to implement the solution. Teachers in collaboration with peers, mentors, or even evaluators define the best resources available to act on and replicate or improve the practice. Teachers may use an online digital library, for example, to access resources centered on formative assessment.

### 1.2 Video Analysis Tool (VAT)

VAT provides evidence capture (e.g., video) and analysis tools (e.g., rubrics) used to define and reflect upon performance and practices [See http://vat.uga.edu/] Teacher practices, for example, are recorded through video cameras and stored on a secure server for review or analysis. Video evidence may be captured two ways: live, real-time capture and post-event upload. In live capture, an IP video camera is pre-installed in a classroom, streaming video to a server which then records the evidence, enabling a rater to observe practices unobtrusively with minimal classroom disruption or interference. Video practices are captured and sent directly to a remote server; neither the teacher nor the leader needs to load, replace, adjust or otherwise "mess with" the technology as the process is automated with preset triggers. Post-event upload refers to archiving video files subsequent to recording a practice. VAT users can videotape an event in real-time, subsequently digitalizing and uploading the converted files. Post-event uploading provides redundancy in the event of network or data transfer failures, as cameras can store video files locally for subsequent uploading.

Video analysis enables users to conduct deep inquiries into leading-teaching-learning practices, enabling the parsing of specific video events and segments into smaller sessions specific to defined areas, needs or priorities. Refined sessions, called Video clips, are especially useful in refining the scope of an inquiry, providing both practitioners and raters the ability to observe and reflect without the 'noise' or 'interference' of extraneous events. The rater accesses captured video evidence from a standard computer using the VAT interface. Through *create clips*, an initially large video segment is created, providing markers or reminders of where target practices might be examined more deeply. After initial live observation or during post-event review, the rater uses the *refine clip* function to make further passes at segments to define specific, finer grained activities, such as when specific inquiry methods occurred. During refinement, the user defines specific clips associated with areas of interest. The user designates, annotates, and certifies specific events clips as representative evidence associated with a target practice, such as a teaching standard (e.g., NSTA Teaching Standards). Marked-up, performance evidence can then be accessed and viewed for either a single practitioner or across practitioners using the *view clips* function, providing raters the ability to examine closely the performance of a single individual across multiple events, or multiple individuals across single events. Finally, through the m*ultiple clips view* function, users can share clips and reflections with other raters or practitioners, reflecting upon and comparing perspectives on, and analysis of, the events.

**2. Concept Map**

Concept-mapping techniques are interpreted as representative of students' knowledge structures and so might provide possible means of tapping into student's conceptual knowledge structure (Yin, Vannides, Ruiz-Primo, Ayala, and Shavelson, 2005, Novak & Gowin, 1984). In the process of thinking, concept maps are the most important of all forms of knowledge for the mental tools of thinking that enable one to understand both the physical and the social worlds, as well as to communicate intelligibility (Sisovic & Bojovic, 2000). The concept map is an approach to estimating human understanding of the relations between events, between ideas, and between human (Saito, Ohuchi, & Maeda, 2005). A concept map is a two dimensional, hierarchical diagram representing interrelation among concepts (Liu, 2004). It includes nodes that are terms or concepts, linking lines which usually with a unidirectional arrow from one concept to another, and linking phases which describe the relationship between nodes. Linking lines with linking phases are called labeled lines. Two nodes connected with a labeled line are called a proposition. Moreover, concept arrangements and linking line orientation determine the structure of the map (Yin et al., 2005, Saito et al., 2005). There are two techniques of concept map, fill in the map and construct the map (Ruiz-Primo, Schultz, Li, Shavelson, 2001, Yin et al, 2005). Fill in the map technique provides students with concept maps and/or the linking words have been left out. Students fill in the blank nodes or blank liking lines. The construction a map technique varies as to how much information is provided by the assessor. The assessor may provide the concepts and/or linking words or may ask students to construct a hierarchical or non- hierarchical map. The variation among maps provide practitioners with the numerous options for use and interpretation, the diversity posed challenges and opportunities for the measurement of achievement. A concept map process variable can be created from students' think aloud while constructing their maps (Yin et al, 2005). The constant revision of concept maps helps students become reflective learner who monitor their understanding and make intentional effort to improve their conceptual understanding (Liu, 2004, Novak & Gowin 1984).

Concept map has been widely use for various purposes such as curriculum planning, teaching, and assessment (Liu, 2004, Ruiz-Primo et al., 2001). It is useful in the educational process when want to measure the result of learning at the end of an educational courses, to see progression of students' learning (Saito et al., 2005, Liu, 2004, Novak & Gowin 1984). Characterization of a concept map assessment based on three components, task, response format, and scoring system. The characteristic of the task, the response format, and the scoring system hold the key for tapping what concept map based assessments are intended to evaluate that is knowledge structure (Ruiz-Primo et al., 2001, Yin et al., 2005). The use of concept map for assessment is justified because this structural dimension of knowledge has not been tapped well by traditional achievement test (Ruiz-Primo, Shavelson, Li, & Schultz, 2001) Yin et al. (2005) applied concept map in to assessment and scored concept map products based on the propositions and structure of the concept map, which are accuracy score, score for the choice that students were use in their concept map, and score for structure complexity. The scoring systems vary from counting the number of nodes and linking lines to evaluating the accuracy of propositions (Ruiz-Primo et al., 2001). There are seven basic things important to look at it during assess concept map which is relationships between topics and concepts. They are (1) definition, (2) characteristic or properties, (3) example, (4) temporal sequence, (5) casual sequence. (6) similarity, and (7) greater than or least then (Surber, 1984).

### 3. Questionnaire

The "Atomic Structure and the Periodic Table Instruction Survey Questionnaire" (see appendix A) will be analyzed for students' perception concerning relative understanding of; and the using video clips and VAST-models for learning; concepts in atomic structure and the periodic table. The questionnaire data analyze using a combination of qualitative and quantitative method. The qualitative analysis analyzes using content analysis find out theme of students' ideas regards using video clips and VAST-models in their learning of atomic structure and the periodic table. In The quantitative analysis, the number of student response in each category will be calculated as a percentage of frequency.

### 4. Concept Tests

The atomic structure and the periodic tests will be analyzed for students' conceptual understanding and problem solving strategies by using a concept-evaluation scheme which adapt from the concept-evaluation scheme of Boujaoude and Barakat (2000). This scheme consisted of four categories: No Conceptual Understanding (NCU), Partial Conceptual Understanding (PCU), Sound Conceptual Understanding (SCU), and no response. NCU

The responses of each student were analyzed using the above scheme to find out the level of their understanding of each of the five concepts and principles included in the test items (molar quantity, limiting reagents, and conservation of matter, molar volume, and coefficient ratios in a chemical equation). Moreover, misunderstandings in each of the concepts were identified. Consequently, each student got a number of scores on each concept depending on the number of questions in which the concept was addressed. Thus, a student got a score of 0, 1, or 2 (NCU, PCU, and SCU respectively) on each situation where the concept was present. Then, an average score on each concept for each student was calculated and the scores on all the five concepts and principles were summed up to a total score. The maximum possible score was 10. A total score of less than four designated NCU, a total score between four and seven (Four is inclusive) designated PCU and a total score of seven and above designated SCU. Then, the students were divided into three groups according to their total scores on the five concepts and principles (see Abraham et al., 1992). Figure 4. Categories of Understanding for Conceptual Chemistry Problems Degree of understanding Criteria for scoring No response Blank, I don't know, I don't understand No conceptual understanding Repeats question, irrelevant or unclear response Partial conceptual understanding and Partial conceptual understanding with specific misunderstanding Responses that show understanding of the concept but also make statements which demonstrate a misunderstanding Responses that include at least one of the components of the valid response, but not all components Sound conceptual understanding Responses that include all components of the valid response Students' written solutions in the stoichiometry test were analyzed and their problem solving strategies w ere described and classified. The analysis was conducted as follows: Every one complete idea that moved the student further towards the answer of the problem, whether the answer was correct or not, was designated as one step. Every solution was analyzed in terms of these complete ideas, and strategies were described for each student according to the number of steps, their sequence, and also according to their conceptual meaning[1]. Note that what might have been a strategy for one problem might be a mere step for another. For example, if a problem asked for the limiting reagent, then finding the limiting reagent was a strategy comprised of a number of steps, whereas finding the limiting reagent might be only one step in a more complex problem.

# CHAPTER IV

# RESULT OF USING THE ATOMIC STRUCTURE AND THE PERIODIC TABLE INSTRUCTIONAL UNITS USING VISUAL SPATIAL MODELS

This chapter discusses classroom practice; teacher teaching and student learning, student understanding of concepts in atomic structure and the periodic table, student visuospatual thinking, and student perspective of using the visuospatial; VAST-models and Video clips in atomic structure and the periodic table instruction for each of the school cases.

## School A

### 1. The Classroom Practice: Teacher Teaching and Students Learning by the Instructional Units Using Visuospatial Models

#### 1.1 Classroom setting

The classroom used by the case study class consisted of four rows tables as shown in figure 4.1. The class was much clouded, there were 10-13 students sat in each row. When doing a group work, the students who sat in the front line were turn back to make a group with the students who sat behind them.

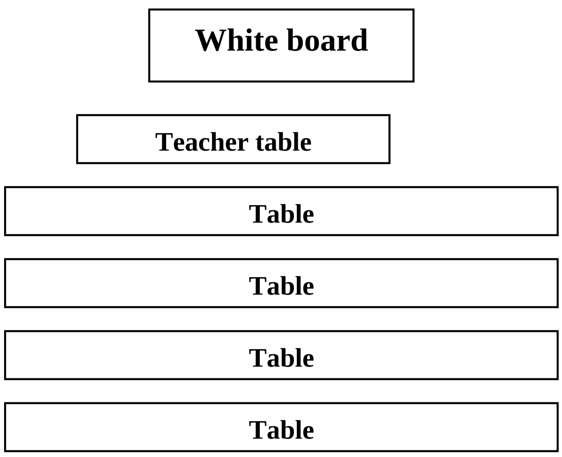



**Figure 4.1** A classroom setting of school A

Since the class setting of school A was like this, students changed their group almost every time they have class.

### 1.2 Visuospatial Models and the Classroom Discussions

Each lesson plan had activity which encouraged students' discussion. Most of the units began with Jandra asking questions explored students' existing knowledge related to concepts which she intended to teach. After that students were required to do activities e.g. experiments or worksheets. The first category of discussion emerged here as students were required to share their experiment result or the answers in worksheet. At the first few periods of the ASPTUs implementation, Jandra asked a class to answer questions. Then she found out that she better asked the individual students because students responded to the questions which not specify responder in two ways; scramble answer and no response. The second category of discussion was with the video clips demonstrations. Students were requested to predict about the possibly occurrence in the video or make a conclusion for the phenomenon which they observed. The finding revealed that students responded actively for the question which needed a conclusion for example the discussion of Thomson's cathode rays tube experiment.

Jandra: Do you think why cathode rays curved to positive charge plate?

Student: They hold negative charge.

Jandra: What's making you think that?

Student 1: Because cathode rays are electrons.

Student 2: Because the same charge object repels each other, on the other hand, the different charges are attracted.

Moreover, the questions were sometime raised by students. During teacher was teaching about quantum numbers and atomic orbitals. One of the students suspected that why half of spin quantum number was negative (+$\frac{1}{2}$) and another half was positive (-$\frac{1}{2}$)

Student 1: Looks, they are in the same sub atomic orbital so why their charges are different.

Student 2: How come? The spin quantum numbers represent two electrons contain in sub atomic orbital, right? Electrons hold negative charge though.

Jandra: O.K. class look at this video (turned on the video of spin quantum number).

Jandra: Anybody see the different?

On this occasion, the teacher did not show the video of spin quantum number at first. The activity here was "Quantum Number and Atomic Orbital". Students were asked to complete the worksheet. This video clips will be omitted if this students did not raised a question. As this occasion, not all video clips were demonstrated. The teacher rather selected for the class whether they should work on worksheet or do a video discussion.

### 1.3 Visuospatial Models and the Experiments

There were two experiments which related to the visuospatial VAST-models and the video clips which required students 'hands-on. Most of the experimental studies were in video clips which students required a discussion. In the "Flame Test" experiment, the video clips of exiting electron "States of Electron According to Bohr's Atomic Model" was selected for explain phenomenon behind the result which students had the teacher let students do an experiment in group and after students communicated their experimental result, the teacher showed students a video of exciting electron. However, in the process of accommodating idea, the teacher explained the relation of the experimental result and the video clip herself.

**Figure 4.2** Students' working with VAST-models

For the activity "VAST-models and Structure of the Element" the teacher asked students to construct the structure of element they have drawn using the VAST-models. Besides, the teacher demonstrated how each atomic orbitals contained in atomic structure before the activity. The teacher of this school case intended to use this activity to test students' understanding of atomic structure. She stated once during the in the interview that;

> "It has been good that we included this activity. It reveals us which point is students still have problem with".

**2. Student Understanding of Concepts in Atomic Structure**

All participant students of school A (44 students) were examined for their understanding of concepts in atomic structure.

**Table 4.1** Numbers and percentages of given answer for the questions about atomic structure of school A students.

| Concepts | Question No. | SU | | PU | | AU | | NU | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** |
| Model | 1 | 2 | 5 | 0 | 0 | 38 | 86 | 4 | 9 |
| Properties of sub atomic particles | 2 | 28 | 64 | 14 | 32 | 0 | 0 | 2 | 5 |
| | 3 | 24 | 55 | 14 | 32 | 3 | 7 | 3 | 7 |
| | 4 | 12 | 27 | 9 | 21 | 0 | 0 | 22 | 50 |
| Atomic model | 5 | 7 | 16 | 0 | 0 | 7 | 16 | 30 | 68 |
| | 6 | 13 | 30 | 24 | 55 | 6 | 14 | 1 | 2 |
| Atomic number, atomic mass, and nuclear symbol | 7 | 32 | 73 | 11 | 25 | 0 | 0 | 0 | 0 |
| | 8 | 35 | 80 | 8 | 18 | 0 | 0 | 1 | 2 |
| | 9 | 35 | 80 | 1 | 2 | 1 | 2 | 7 | 16 |
| | 11 | 34 | 77 | 0 | 0 | 7 | 16 | 3 | 7 |
| Isotope and atomic mass | 10 | 29 | 66 | 6 | 14 | 4 | 10 | 5 | 9 |
| | 12 | 14 | 32 | 0 | 0 | 22 | 5 | 8 | 18 |
| | 13 | 26 | 59 | 10 | 23 | 0 | 0 | 8 | 18 |
| Wave properties of atom and atomic spectra | 14 | 28 | 64 | 5 | 11 | 1 | 2 | 10 | 22 |
| | 15 | 8 | 18 | 18 | 41 | 0 | 0 | 18 | 41 |
| Atomic orbitals and electron configurations | 16 | 35 | 80 | 5 | 11 | 0 | 0 | 4 | 9 |
| | 17 | 15 | 34 | 14 | 32 | 11 | 25 | 4 | 9 |
| | 18 | 25 | 57 | 9 | 21 | 9 | 21 | 1 | 2 |
| | 19 | 22 | 50 | 17 | 39 | 2 | 5 | 3 | 7 |

SU = sound understanding, PU = partial understanding, AU = alternative understanding, NU = no understanding.

The results are discussed following the main concepts in atomic structure. The numbers and percentages of students' given answers are in Table 4.1. Students' understandings of each concept in atomic structure were discussed as the following.

### 2.1. Model

Since this research study emphasized on using visual spatial models for instruction, the concept of model was asked. Gilbert (2005) indicated that there are five modes of model representation; concrete mode, verbal mode, symbolic mode, virtual mode, gesture mode. Only two students (5%) held a sound understanding for the concept, stated that the verbal statement of Democritus's atomic theory is a model. Most of the students (38 students, 86%) held alternative understandings; twenty three students stated that verbal statement is not a model (52%), eleven students (25%)

stated that models need experimental result supported, and four students (9%) stated that models are only in a concrete form.

### 2.2 Properties of Sub Atomic Particles

Students were asked to indicate properties of sub atomic particle (proton, electron, and neutron) along with the experimental study of scientists. Concerning the concept of proton properties, Most of the students (28 students, 64%) held sound understanding that positively charge proton moved toward cathode which has negatively charge. Fourteen students (32%) held partial understandings, stated correctly that proton has positively charge, but remained with problems of understanding and confusion, could not specified charge of electrodes (cathode and anode) (7 students, 16%), electric attraction/repulsion of proton and the electrodes (5 students, 11%) and both (2 students, 5%).

Regards to the concept of properties of electrons (cathode ray), found most of the students (24 students, 55%) held sound understanding: Thomson made a conclusion that cathode rays hold negatively charge because they were attracted by anode which has positively charge. Fourteen students (32%) held partial understanding, stated that cathode rays hold negatively charge because they were deflected by electric field and magnetic field. However, this could not be a conclusion because protons also deflected by electric field and magnetic field. Three students (7%) held alternative understanding; two students (5%) stated that cathode rays contain positively charge because they were deflected by magnetic field and electric field; one student (2%) stated that cathode rays have positively charge because it was attracted by cathode which holds negatively charge.

In the concept of properties of nucleus students were asked to predict result of shooting $\alpha$-particle into nucleus. Twelve students (27%) held sound understanding that $\alpha$-particle will return from the gold foil in the same direction from which it had come because both nucleus and $\alpha$-particle have positively charge. Nine students (21%) held partial understanding that $\alpha$-particle will return from the gold foil in the same direction from which it had come because nucleus is weighty. However, none of the student held alternative understanding for this concept.

### 2.3 Atomic Models

To explore students' conception about atomic structure, students were asked to predict the result of Rutherford's gold foil experiment. Seven students (16%) held sound understanding that most of $\alpha$-particles passed through the foil with little or no deflection because most of atomic area is empty space. Seven students (16%) held alternative understanding. The alternative understanding was the most of $\alpha$-particles passed through the foil were deflected at very small angles because atom had negatively charged electrons stuck into a lump of positively charged proton (6 students, 14%). This could be interpreted that they held the plum pudding atomic model of Thomson. Another alternative understanding found was the most of $\alpha$-particles were deflected at large angles because they hit the positively charge particles in the nucleus (1 student, 2%). This could be referred that the student focused only on nucleus not a whole atom.

In addition, students' mental model of an atom was explored. Second Most of the students (13 students, 30%) held mental model of atom as quantum mechanical model of an atom (reason most/scientific model) which referred to the probability of finding an electron within a certain volume of space surrounding the nucleus. Most of the students (17 students, 39%) held Bohr's atomic model. They mentioned that electrons traveled in a particular path as fixed energy level. The last one (7 students, 16%) was Thomson's atomic model. Students mentioned that electrons stuck into a lump of protons, dispersed through an atom.

### 2.4 Atomic Number, Mass Number and Nuclear Symbol

The definition of atomic number and mass number were asked. Most of the students (32 students, 73%) held sound understanding that atomic number is the number of proton in atom, if an atom lost or gained proton the element will be changed. Eleven students (25%) held partial understanding that atomic number is the number of electron. This answer correct only with atoms which has equal number of protons and electrons not including ions. As well as mass number, Most of the students (35 students, 80%) held sound understanding, stated that mass number is the sum of protons number and neutrons number. They gave a reason supported that compared to mass of protons and neutrons, mass of electron is very less. However, eight students (18%) held partial understanding, stated that mass number is the sum of protons number and neutrons number, however the reason for choosing the answer were not correct, five students (11%) gave a reason that electrons moving all the time so can not accurate their mass, and three students (7%) gave a reason that electrons have no mass.

About the nuclear symbol, students were asked to indicate nuclear symbol of the element which has 18 electrons. Most of the students (35 students, 80%) held sound understanding, answered that nuclear symbol of the element is $^{40}_{18}Ar$ . They explain that the element which has 18 particles electron will also has atomic number 18 which is Argon. Moreover, Argon has 22 neutrons so has atomic mass of the element is 40. according to nuclear symbol of element, atomic number is wrote as a subscript in the lower left corner and the mass number as a superscript in the upper left corner. One student (2%) held partial understanding, confused about location of atomic number and atomic mass (paced atomic number at superscript and atomic mass at subscript). One student (2%) held alternative understanding stated that could not determine atom of element by using number of proton.

Students were also asked to interpret nuclear symbol of $S^{2-}$. Most of the students (34 students, 77%) held sound understanding. They stated that $S^{2-}$ has 16 protons and mentioned to the constant proton numbers of elements. The alternative understanding found was $S^{2-}$ had 18 protons because there were two electrons added (7 students, 16%). This could be inferred that in their opinion, number of protons and electrons always equal even in ions.

### 2.5 Isotope and Atomic Mass

To find out students' understanding of isotope, students were asked to determine whether $_{6}X$ and $^{12}C$ the same element. Most of the students (29 students, 66%) held sound understanding that both elements were the same element, Carbon. Six students (14%) held partial understanding, correctly defined that isotopes are the same element which consist of different masses. However, they mentioned that X may be not Carbon. This could be interpreted that students did not really understand what isotopes are, especially the term "same element" which refers to the same atomic number. Four students (9%) held alternative understanding that $_{6}X$ and $^{12}C$ were not the same element because mass of the element X could be vary. This showed again the alternative understanding about relationship between atomic number and isotopes.

For atomic mass students were asked to predict amount of two isotopes in nature. Fourteen students (32%) held sound understanding that an isotope which had mass number closer to atomic mass of the element found more in the nature because atomic mass is a weight average of the element, calculate from measured isotopic abundances. Twenty two students (50%) held alternative understanding; seventeen students (39%) stated that they did not have enough information for the interpretation, and five students (11%) stated that the isotope which has higher mass number is easier to find in the nature because it is bigger.

Furthermore, students were asked to calculate atomic mass of isotope. Most of the students (26 students, 59%) held sound understanding for the concept; atomic mass is a weight average of isotopic abundances. Ten students (23%) held partial understanding; four students (9%) used the formula: atomic mass = atomic number of isotope x abundant percentage of the isotope +…, but did not use a specific unit (amu.), and six students (14%) answer only the formula but did not show the solution of problem solving.

### 2.6 Wave Properties of Atom and Atomic Spectra

Students were asked to calculate wavelength of yellow light. Most of the students (28 students, 45%) held sound understanding for the concept, used the correct formula to solve the problem and succeed in calculation. Only five students (11%) held partial understanding as mentioned correctly about the formula: $\lambda = \frac{c}{\upsilon}$, where $\lambda$ was wavelength of the yellow light, $c$ was the speed of light, and $\upsilon$ was frequency of the yellow light but did not show the solution for the question. Student (1 student) even held alternative conception for this concept. The alternative conception found was used incorrect formula to solve the problem.

In addition, students were asked to calculate quantum energy. Eight students (18%) held sound understanding for the concept. Students did correctly problem solving, correctly conversed the unit (angstrom to meter), and used correct formula to solve the problem ($E = \frac{hc}{\lambda}$, where $E$ was quantum energy, $c$ was the speed of light, and $\lambda$ was a wavelength). Most of the students (18 students, 41%) held partial understandings. Seven students (16%) mentioned the correct formula but did not show problem solving. Nine students (20%) did not use a specific unit of wavelength (meter). And found one student (2%) did an incorrect calculation so the answer was incorrect.

### 2.7 Atomic Orbitals and Electron Configurations

Students were asked to indicate an electron arrangement of an element. Most of the students (35 students, 80%) held sound understanding for the concept. Thirty one students (71%) were able to use both Aufbau's diagram and the periodic table (noble gas) for electron configurations. Three students (7%) were able to use only the periodic table to indicate an electron configuration of the element, and one student (2%) was able to use only Aufbau order of filling. Five students (11%) held partial understanding that stated correctly about energy levels (shells) but had confusion about order of orbitals.

Besides this, students were asked to examine the given electron configuration and reasons for electrons' behavior. Most of the students held sound understanding for the concept. Fifteen students (34%) stated that electrons were fulfilled the lowest energy level before enter the next energy levels. Twenty five students (57%) indicated that electrons tried arrange as half-filled or filled set of orbitals for enhancing stability of the element. Moreover, half of the students (22 students, 50%) even knew that electrons in *3s*-orbitals never jump to *3p*-orbitals although for half-filled or filled set arrangement because of the large energy gap between *3s* and 3*p* orbitals. The partial understandings found were: students were able to use Aufbau's diagram for electron configuration but confused about a written order of orbitals in electron configuration, stated that to write all sets of orbitals with the same energy level value together ([Ar] $3d^{10}4s^{1}\ 4p^{6}$) and to write follow the Aufbau order of filling ([Ar] $4s^{1}3d^{10}4p^{6}$) were different (14 students, 32%); and students did not know the main reason for electronic skipping form orbital *ns* to orbital (*n*-1)*d* of transition elements, mentioned to orbitals overlapping but did not address to stability enhancing (9 students, 21%), and students did not concern about the half-filled and filled set of orbitals in electron configuration of the transition elements (9 students, 21%).

In the other hand, did have a group of students which too focused on the stability enhancing to concern about the gap between *3s*-orbitals and *3p*-orbitals, addressed that electrons in *3s*-orbitals would jumped to *3p*-orbitals for half-filled arrangement of the electron configuration (17 students, 39%) which is an alternative understanding. The other alternative understandings found was students did incorrectly the order of orbitals in electron configuration (2 students, 5%); students did not know length of gap between orbitals, mentioned to electronic skipping between orbitals which energy level not close to each other e.g. *4s*-orbital and *4p*-orbital (6 students form Q17 and 2 students from Q19).

**3. Student Understanding of Concepts in the Periodic Table**

All participant students of school A (44 students) were examined for their understanding of concepts in the periodic table.

**Table 4.2** Numbers and percentages of given answer for the questions about the periodic table of school A students.

| Concepts | Question No. | SU | | PU | | AU | | NU | |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | *%* | *n* | *%* | *n* | *%* | *n* | *%* |
| The periodic table and electron configuration | 20 | 33 | 75 | 0 | 0 | 0 | 0 | 11 | 25 |
| Chemical properties and a physical properties of metals, nonmetals, and metalloids | 21 | 21 | 48 | 7 | 16 | 14 | 32 | 4 | 10 |
| | 22 | 31 | 71 | 0 | 0 | 12 | 27 | 0 | 0 |
| | 23 | 38 | 86 | 4 | 9 | 0 | 0 | 2 | 5 |
| | 24 | 16 | 36 | 5 | 11 | 5 | 11 | 17 | 39 |
| | 25 | 33 | 75 | 0 | 0 | 10 | 23 | 1 | 2 |
| | 26 | 26 | 59 | 0 | 0 | 9 | 20 | 9 | 20 |
| Atomic radii | 27 | 22 | 50 | 0 | 0 | 15 | 34 | 7 | 16 |
| Ionization energy | 28 | 34 | 77 | 0 | 0 | 3 | 7 | 7 | 16 |
| | 29 | 32 | 73 | 3 | 7 | 3 | 7 | 6 | 14 |
| | 31 | 5 | 11 | 26 | 59 | 0 | 0 | 13 | 30 |
| | 32 | 10 | 23 | 22 | 50 | 0 | 0 | 12 | 27 |
| Ionic radii | 30 | 12 | 27 | 17 | 39 | 11 | 25 | 2 | 5 |
| Electronegativity | 33 | 14 | 32 | 0 | 0 | 4 | 10 | 26 | 59 |
| | 34 | 2 | 5 | 30 | 71 | 0 | 0 | 12 | 29 |
| Electron affinity | 35 | 2 | 5 | 0 | 0 | 37 | 88 | 5 | 12 |
| | 36 | 25 | 57 | 0 | 0 | 12 | 27 | 7 | 16 |
| Melting point and boiling point | 37 | 28 | 64 | 5 | 11 | 3 | 7 | 8 | 18 |
| | 38 | 30 | 68 | 3 | 7 | 2 | 5 | 9 | 21 |
| Oxidation number | 39 | 14 | 32 | 0 | 0 | 20 | 45 | 10 | 23 |
| | 40 | 23 | 52 | 0 | 0 | 13 | 30 | 8 | 18 |

SU = sound understanding, PU = partial understanding, AU = alternative understanding, NU = no understanding.

The results are discussed following the main concepts in the periodic table. The number and percentage of students' given answer show in Table 4.2. Students' understandings of each concept in the periodic table were discussed as the following.

## 3.1 The Periodic Table and Electron Configuration

Students were asked to determine group and period in the periodic table of an element. All of the students who completed the answer (33 students, 75%) held sound understanding for the concept, were able to use electron configurations to specify group and period of the element, and correctly stated that the outer most energy level indicate period, and valence electron indicate group of the element. However, students used different methods in demonstrating electron configurations of the element. Most of the students (12 students, 27%) used noble gas configuration (the periodic table), ten students (23%) used Aufbau's diagram, eight students (18%) used Bohr's diagram, and three students (7%) showed all three methods of electron configurations.

### 3.2 Chemical Periodicity of Elements

The eight concepts of chemical periodicity of element were inquired; (1) chemical and physical properties of metals, nonmetals, and metalloids, (2) atomic radii, (3) ionization energy, (4) ionic radii, (5) electronegativity, (6) electron affinity, (7) melting point and boiling point, and (8) oxidation number.

#### 3. 2.1 Chemical and Physical Properties of Metals, Nonmetals, and Metalloids

Students were asked to predict the stability of atoms and ions, compare stability of Zinc and Rhodium, and also compare stability of Sulfur and Sulfur ion ($S^{2-}$). Most of the students held sound understanding for the concept; twenty-one students (48 %) stated that Zinc was more stable than Rhodium and thirty one students (71%) stated that Sulfur ion was more stable than Sulfur because Zinc and Sulfur ion hold filled arrangement of the electron configuration. The partial understanding found in this issue was that transition elements hold the same properties therefore the stability of Zinc and Rhodium (7 students, 16%). There were also alternative understandings emerged. Twelve students (27%) held alternative conception about size of atom and stability: eight students (18%) stated that the bigger atom (Rhodium) is more stable, and four students (10%) stated that smaller atom (Zinc) is more stable. Eleven students (25%) held alternative understanding about electron repulsion, stated that the two extra electrons of Sulfur ion caused the Sulfur ion to be less stable compared to Sulfur (atom). Two students (5%) held alternative conception that the same element has same properties either in form of atom or ions (Sulfur atom and Sulfur ion hold the same stability).

Students were asked about the malleable ability (can be hammered into sheets) and ductile ability (can be drawn into wires) of metals. Most of the students (38 students, 86%) held sound understanding, stated that metals have malleable ability and ductile ability because mobile electrons of metallic bonding belong to the whole metallic crystal. Four students (9%) held partial understanding stated that metals have malleable ability and ductile ability. However, three students (7%) stated that only massive metals hold malleable ability and ductile ability and one student (2%) stated that malleable ability and ductile ability depend on size of metal atom. Only electrons of small metal atom are able to mobilize their neighbor atom, on the other hand, electrons of big atom could not.

Students were asked about properties of nonmetal elements. Most of the students (16 students, 36%) held sound understanding, stated that not all the nonmetal elements are gases and that the massive nonmetal elements are solids. Five students (11%) held partial understanding stating that nonmetal elements have low melting and boiling points so they were all gases. However there are some low melting point and boiling point nonmetals in the form of a solid (e.g. Phosphorus) and liquid (e.g. Bromine). Five students (11%) held alternative understandings for the concept. Four students (9%) stated that all of nonmetal elements are gases because nonmetals form covalent bonding. This statement also revealed another alternative understanding: covalent molecules are gases. Another alternative understanding found was that nonmetals were small in size compared to metals and metalloids in the same period of the periodic table and the small atom of nonmetals are light. The light nonmetal atoms are floatable as gases (2%).

Students were asked to examine conductivity of metalloids. Most of the students (33 students, 75%) held sound understanding that the conductivity of metalloid were getting better after heating because electrons of heated metalloids were moving faster. However ten students (23%) held alternative understandings. The alternative understandings found were: at higher energy levels electrons of metalloid form metal bonding so they have better conductivity (7 students, 16%), and metalloids had no conductivity because they form covalent bonding (3 students, 7%). The last statement revealed one more alternative understanding: covalent molecules have no conductivity. Surprisingly, students forgot that Germanium, Silicon, and compounds of Arsenic and Antimony are the most important semiconductors.

Students were asked to determine the reason which causes high stability in noble gases. Most of the students (26 students, 59%) held sound understanding, gave a reason that because of noble gases hold filled arrangement of the electron. Nine students (20%) held alternative understandings for the concept; eight students (18%) stated that this is because of the electric attraction force between protons and electrons of noble gas atoms, their highest number of electron and protons resulted in the highest attraction force. This causes them tend to not lose or share their electrons for bonding, and a student (2%) gave a reason because of their size, they are smallest and hold strongest attraction force in the period so difficult to release their electrons.

### 3.2.2 Atomic Radii

Students were asked to determine atomic radii from electron configuration. Most of the students (22 students, 50%) held a sound understanding that atomic radii of the atom which has electron configuration $1s^2 2s^2 2p^6 3s^1$ was not the smallest atom of the period which it occupied. The smallest atom of each period was in group VIIA, not group IA as this atom. Fifteen students (34%) held alternative understandings; twelve students (27%) stated that the smallest atoms are in group IA, and three students (7%) stated that the orbital 3*s* filled two electrons so atom of $3s^1$ is the smallest in the period. This indicated that students have an alternative concept about orbitals in each electron energy level as well as electric attraction force.

### 3.2.3 Ionization Energy

Students were asked to predict what occurred to the ionized atoms. Most of the students held sound understanding. Thirty-four students (77%) stated that when a sodium atom lose its first electron the remaining ten electrons in the sodium ion ($Na^+$) will experience greater attraction by the nucleus. Thirty-two students (72%) stated that the ionization energy to remove the second electron from $Na^+$ was greater than the ionization energy of the first electron because the greater electrical attraction force between the remaining electron and nucleus (20 students, 46%) and the second electron occupied in the energy level which was closer to nucleus than the first electron (12 students, 27%). However, only ten students (23%) made a right conclusion that the ionization energy of positive ions was always greater than the neutral atoms because their electric attraction force (protons and electrons) was greater. The partial understanding found were; The $Na^+$ ion has a stable/noble gas configuration, so it preserves stability and does not lose anymore electron (3 students, 7%) and ionization energy of positive ions were always greater than the neutral atoms because the second electron occupied in the energy level was closer to nucleus than the previous one (22 students, 50%). This statement is not always true because sometime the second electron is still in the same energy level as the first electron. The alternative understandings found were; the amount of attraction force between an electron and the nucleus depends on the number of protons presented in the nucleus and the distance of the electron from the nucleus. It does not depend on how many electrons were presented, although electrons do repel each other (3 students, 7%), the electron which is removed will take away the attraction of the nucleus with it when it leaves the atom (3 students, 7%).

Furthermore, students were asked to find out trend of the first ionization energy ($IE_1$) of Beryllium (Be), Boron (B), Nitrogen (N), and Oxygen (O). Only five students (11%) held sound understanding. They indicated the trend is

N>O>Be>Be and gave explanation that the $IE_1$ increase generally as moving from left to the right across a period of the periodic table. However, Boron and Oxygen rather lose their electrons for their stable half-filled and filled electron configuration so $IE_1$ of Beryllium was greater than Boron and Nitrogen was greater than Oxygen. The partial understanding was students gave the right explanation of $IE_1$, however forgot the exception, answered O>N>B>Be. The right explanation found was; $IE_1$ generally increase as moving from left to the right across periods of the periodic table (14 students, 32%), and $IE_1$ depended on size of atoms, the smaller atoms hold the higher $IE_1$ (12 students, 27%).

### 3.2.4 Ionic Radii

Students were asked to compare ionic radii of fluoride ion and sodium ion. Twelve students (27%) held sound understanding that the fluoride ion is bigger than the sodium ion because both ions have the same electron configuration. However the sodium ion has a higher number of protons. The partial understanding was found at the highest percentage, 39% (17 students). Students stated correctly that the fluoride ion is bigger than the sodium ion but gave an incorrect reason that negative ions are always bigger compared to positive ions. Actually, this statement is correct only with negative ion and positive ion of the same element and cannot refer to ions of different elements. Eleven students (25%) held alternative understanding, ions which have the same electron configuration, the lower protons ion is smaller in ionic radii (10 students, 23%), and ions which have the same electron configuration have the same ionic radii (1 student, 2%).

### 3.2.5 Electronegativity

Students were asked to order electronegativity of Beryllium (Be), Iron (Fe), germanium (Ge), and Tellurium (Te). Most of the students (14 students, 32%) held sound understanding, indicated Te>Ge>Fe>Be and stated that electronegativities increase from left to right across period and decrease from top to bottom within group of the periodic table. The alternative understanding that emerged was the bigger atoms have greater electronegativity (4 students, 9%).

In addition, students were asked what they expected when Hydrogen (H) bonds with Fluorine (F) to form a Hydrogen fluoride molecule (HF). Only two students (5%) held sound understanding that electron tendency is attracted to fluorine because its electronegativity is higher. Most of the students (30 students, 71%) held partial understandings; nineteen students (43%) stated correctly that electron is attracted to Fluorine, Hydrogen will lose its electron form Hydrogen ion ($H^+$) and Fluorine will receive the lost electron from Hydrogen form Fluoride ion ($F^-$). Eleven students (25%) stated correctly that HF is a covalent molecule so both Hydrogen and Fluorine are sharing their electrons. However, students missed that HF is a polar molecule, so they stated that electron tendency is in the middle.

### 3.2.6 Electron Affinity

Students were asked to characterize electron affinity of metals. Only two students (5%) held sound understanding, stated that electron affinities of metals are negative and the addition of an electron to form anion of metals is exothermic. Most of the students (37 students, 88%) held alternative understandings. The alternative understandings found were: to add electron to metal atoms require pushing energy because metals prefer to be cations (positive ions) (15 students, 34%), positive electron affinity need for cations forming (10 students, 23%), the electron affinity of exothermic reaction is positive value (9 students, 21%), and it is impossible to form metal anions (negative ions) (3 students, 7%).

However, when students were asked to interpret equation $K (g) + e^- \longrightarrow K^- (g) + 48$ kJ, EA = -48 kJ/mol. Most of the students (25 students, 57%) held sound understanding for the concept that to form potassium anion, the potassium atom needed to release energy because of the energy requirement for bond breaking and release in the bond formation. The alternative understandings found were; negative electron affinity means energy required for the reaction is less than zero (7 students, 16 %), and again the alternative understanding persisted, it is impossible to form potassium anions (5 students, 11%).

### 3.2.7 Melting Point and Boiling Point

Students were asked to predict melting point and boiling point of small size metals. Most of the students (28 students, 64%) had a sound understanding that small size metals had a high melting point and boiling point because their close packed crystals needed high energy for breaking out. Partial understanding found was not only small size metals hold high melting point and boiling point but all metals are also high melting point and boiling point (5 students, 11%). The alternative understanding found was the small size metals have low melting point and boiling point because they are low in mass so need not much energy for breaking out their crystals (3 students, 7%). This statement also exposed students' confusion about melting point and boiling point of covalent molecules and metallic crystals. The huge covalent molecules hold high melting point and boiling point but the metallic crystals are on the other hand, smaller metal atoms resulted higher melting point and boiling point of metallic crystals.

Moreover, students were asked to consider melting point and boiling point of metals and nonmetals. Most of the students (30 students, 68%) held sound understanding that melting point and boiling point of metals is higher than nonmetals because metal's bond of metals is stronger than covalent bond of nonmetals. The partial understanding found was students employ an exception of nonmetals for their consideration. Students stated the nonmetals in group VIA hold coordinate covalent bond which is stronger than metal bond, so it's also higher in melting and boiling point (3 students, 7%). However, this phenomenon only occurred with nonmetals in this group. The alternative understanding found was students stated that one cannot compare melting point and boiling point of the different elements (2 students, 5 %).

### 3.2.8 Oxidation Number

Students were asked to indicate oxidation number of Sodium (Na) in Sodium nitrate ($NaNO_3$). Most of the students (14 students, 32%) held sound understanding, stated that Sodium has oxidation number +1 because elements in Group IA always have oxidation number +1. The alternative conceptions found were; oxidation number of element equal oxidation number of the compound which the element composed (11 students, 25 %), oxidation number of element is zero even in the compounds (7 students, 16%), and single atom in compounds had oxidation number +1 (2 students, 5%).

Students further enquired to compare oxidation number of Sulfur (S) in the Sulfuric acid ($H_2SO_4$) and Sulfur dioxide ($SO_2$). More than half of students (23 students, 52%) held sound understanding that oxidation number of S in the compounds is different, +6 in $H_2SO_4$ and +4 in $SO_2$, and explained that oxidation number of each element is varied depending on compound that existed. Alternative understandings found were; the same element always hold the same oxidation number (8 students, 18%), and again students still mentioned that oxidation number of elements is always zero even in compounds (5 students, 11%).

## 4. Student Visuospatial Thinking

All 44 students of school A were examined their visuospatial thinking all the way through the implementation of atomic structure and the periodic table instructional units by concept mapping and classroom activities deal with the VAST-models, video clip animations, and narration text/lecture. Additionally, six students from the class were interviewed at the end of the instructional units implementation. Student visuospatial thinking of atomic structure and the periodic table were deliberated as the following.

## 4.1 Student Visuospatial Abilities on Atomic Structure

### 4.1.1 Atomic Models

To study student learning concepts in atomic structure, students were demonstrated atomic models of the scientists and also the atomic model students used along with their explanations for the concepts. The atomic models which often mentioned in students' works were atomic models of Democritus, Dalton, Thomson, Rutherford, and Bohr. The quantum mechanical atomic model of Schrödinger often referred as electron cloud model. According to atomic models representations, students had images of the atomic structure in their mind (mental model) and they merely presented them out. There were two groups of the demonstrations, verbal explanations and figures. For example, a case of verbal explanation, students imaged figure of the atomic structures and then described it in their language.

> "Atom included the positive atomic nucleus which combined with protons in the center of an atom and negative electrons moving around the nucleus in large area".(Rutherford's atomic model)

Although students choose figures represented atomic models, they all added statement for more explanation of the figures. Students also used visual analogy to describe atomic models e.g. billiard ball (Dalton's atomic model), plum pudding (Thomson's atomic model), etc. Albeit these visual analogies were used in textbooks and lectures, however, they shaped students an obvious perspective of those atomic models.

Atomic models appeared alternative understandings for school A students were Bohr's atomic model and quantum mechanical atom model. Students' demonstrated electron energy levels in equal distant from the nucleus (see Figure 4.3), contrasted their mention which was the remote electron energy levels getting closer to each other.

**Figure 4.3** Bohr's atomic model of school A student

Some students exposed low spatial ability, indicated that the two drawing styles of Bohr atomic model, as Figure 4.4, were different.

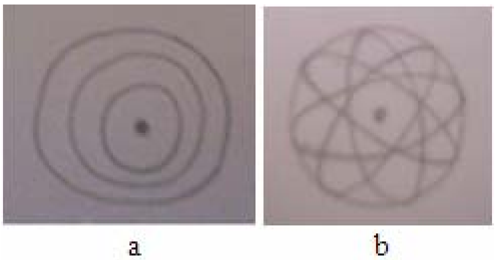



**Figure 4.4** Two drawing styles of Bohr's atomic model

There was also found another low spatial ability about atomic model demonstrated. The study found some students did not concern the density of electron cloud in specific area of atomic structure. Students presented almost the same density in every area. This was congruent with the previous finding, the lack of concerning in distances between the electron energy levels. Moreover, even though students stated their understanding of abstract concepts and structure of atom was enhanced by using VAST-models. They still held low visuospatial ability in atomic structure, the transition between the three-dimensional VAST-models and the drawing two-dimensional images still a problem for students. Most of the students could not draw three-dimensional quantum mechanical model of atom albeit students who were able to draw atomic orbitals. One student stated;

> "Orbitals locate in the each energy level as in the model (pointed to VAST-models). They cover each other belong to the electron energy levels"

In addition, the incapable of drawing of complex *d* and *f* orbitals was dominant. Student avoided drawing by using visual analogy instead (see Figure 4.5).

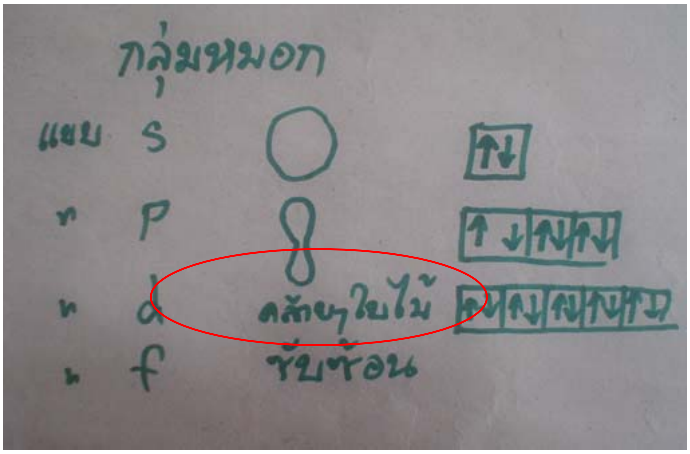



**Figure 4.5** The visual analogy used for the complex atomic orbitals

An atomic model which students preferred using in their explanation was Bohr' atomic model. Even high spatial ability students still used the Bohr model in stead of using the quantum mechanical model of atom which is the most accepted atomic model nowadays. The following is the sample discussion between a high spatial ability student and the researcher;

> R: Why did you use the Bohr's atomic model explain phenomena in atom, why not use the quantum mechanical model which you told me it's the reasonable atomic model?

S: Well…it's easier to use Bohr's model. You see here, how could I use the electron cloud model to explain about electron ionization.

### 4.1.2 Experiments Study of Sub Atomic Particles

Students explicated the properties of sub atomic particles in term of moving particles instead of seeing them as static objects. Most students described what occurred in the experiments before concluded properties of each sub atomic particle. For example property of electron, students did not just state "electron hold negatively charge" rather they explained what happened in cathode rays tube;

> "Thomson passed electric current into the cathode rays tube and found the cathode rays were attracted by anode (+ charge) and deflected by cathode so concluded the cathode rays is negative charge particle".

The representation about the experiments also found in two categories, verbal explanation and figure of the experiments. There was again the experiment figures came along with text descriptions (see Figure 4.6).

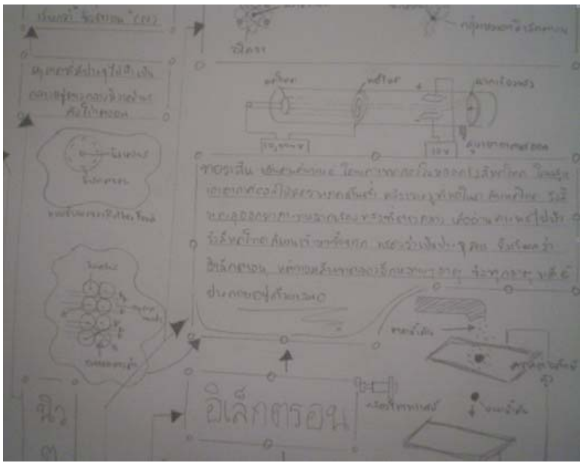


**Figure 4.6** Experiments study of atomic structure and the properties of sub atomic particles

The experiments students usually demonstrated in their works and gave correctly descriptions were the experiments obtained in the video clips which the teacher used in her teaching. Students were unable to construct a dynamic mental model of experimental processes by merely reading texts or viewing two-dimensional diagrams. Students faced difficulty explained the experiments which not included in the video clips, even those experiments were explained very clearly in their chemistry text book. To explain the experiment during the interview, students used visual analogy (gesture) very often. For exampled the gold foil experiment of Rutherford, students used a fist as the atomic nucleus and a finger as the directions of $\alpha$ -particle;

> "If Thomson's atomic model correct, positive particles and negative particles will disperse to entire atom, the rays of $\alpha$ -particles must go like this" (pointed to every direction).

### 4.1.3 Atomic Spectra

Very few students form school A demonstrated figure in their explanation of atomic spectra. Most of them used the equation E = *hv*, where E is quantum energy, *h* is the Planck's constant, 6.626 x $10^{-34}$ J.s, and ν is the frequency of the light, explained the spectrum concept. The equation, E = *hv*, manifested vividly upon students' mind. Some students could not specify the meaning of variables, however, was able to indicate the equation. The figure demonstration of spectrum was simple (see Figure 4.7). Students did not display electron energy levels in atom and showed only two energy levels (grounded and excited energy levels). This figure could interpret in two ways. Firstly, students imaged that the grounded energy level and the excited energy level (must) next to each other, which is an alternative conception. Secondly, student imaged only the ground state and excited state of electron.

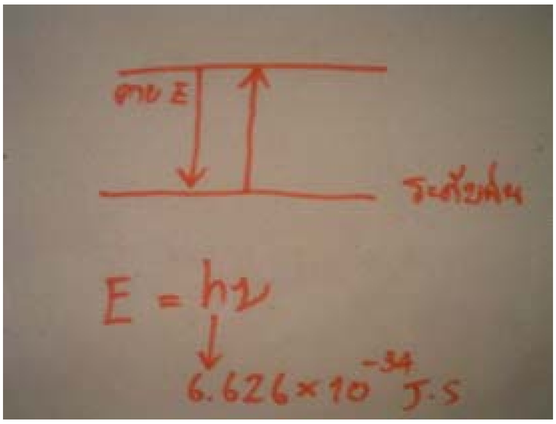



**Figure 4.7** The explanation for spectrum

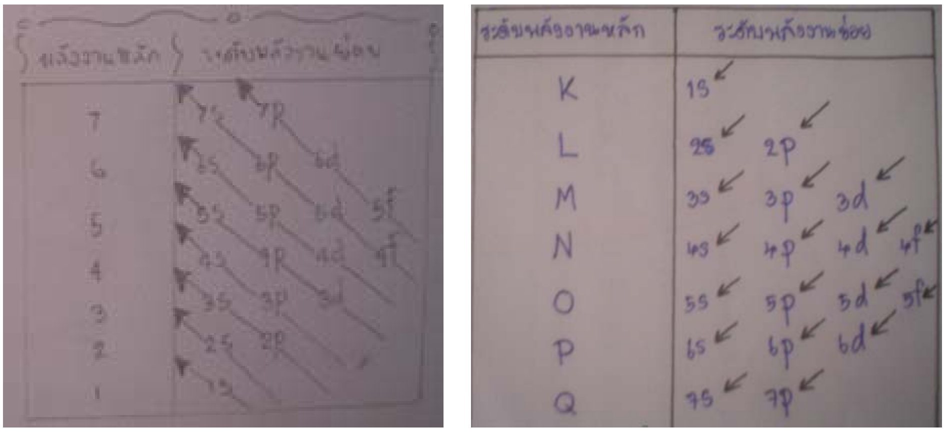
In addition, students who comprehend visual representation at the macroscopic level were also found. Students used what they saw in the frame test experiment to explain spectrum.

> "Normally, the elements are stable. But if…it's like when we did an (frame test) experiment. We held an element over fire and the element exploded a color frames. We called the color frame a spectrum".

#### 4.1.4 Electron Configurations

There were two styles of electrons configuration found in students works and their explanation during the interview, Bohr' diagram and Aufbau's diagram. The electron configuration using the periodic table (noble gases) was barely found. Among the students who using Bohr's diagram, there were students who used the formula, $2n^2$ (where n is electron energy level) and students who held image of the number pattern, 2 8 18 32. Students who used the number pattern not even know how come of those numbers. However, students who succeed in the electron configuration using Bohr' diagram, both formula and number pattern, required visuospatial thinking of the periodic table which composed only eight group of elements. Thus some time the diagram has an exception e.g. $_{20}Ca$ hold electron configuration 2 8 8 2 instead of 2 8 10, even though the third energy level could hold 18 electrons.

The Aufbau's diagram played important role in the electron configuration demonstrated the orbitals. Students drew the Aufbau's diagram before doing an electron configuration always. However, for the first few orbitals students did remember the pattern, no need to draw the diagram. The Aufbau's diagram of students usually came along with the electron energy levels (see Figure 4.8).




**a.** **b.**

**Figure 4.8** Aufbau's diagram

Unexpectedly, as was mentioned above in the topic of atomic models. Students were not able to image three-dimensional atomic structure by visualizing two-dimensional Aufbau's diagram. Moreover, students could not identify the atomic orbitals contained in each energy level. This proved the consistency of low spatial ability in atomic structure.

Perceptual experience included viewing and manipulating with concrete VAST-models for atomic structure helped students construct a more concrete understanding between concepts and representation. Students were able to construct three-dimensional atoms, isotopes, and ions of elements and indicated the properties of them using VAST-models see. For example, the activity "VAST-models and Atomic Structure" are shown in Figure 4.9.

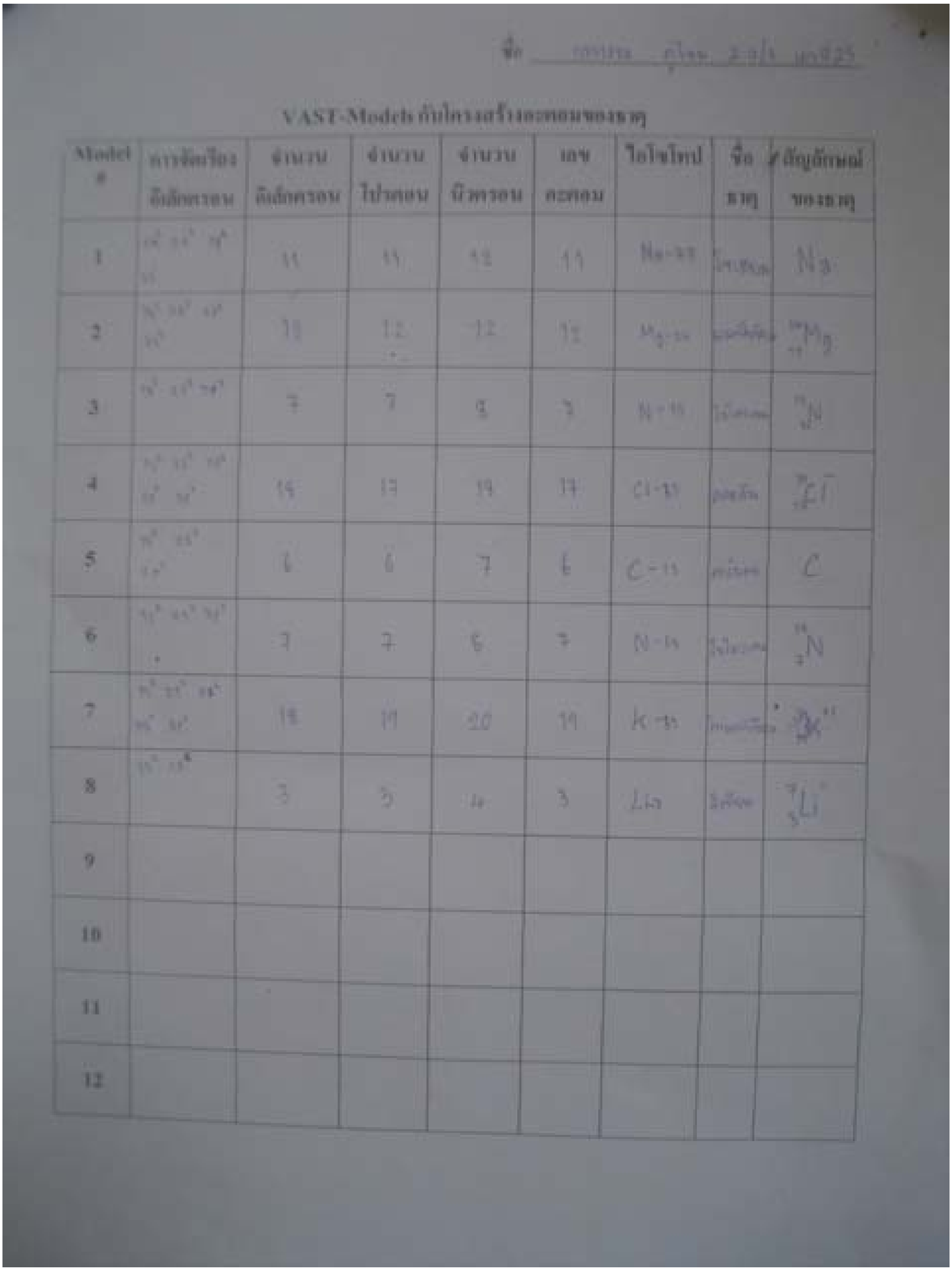


**Figure 4.9** School A students' paper work

## 4.2 Student Visuospatial Abilities on the Periodic Table

### 4.2.1 Position of Elements in the Periodic Table

School A students usually omitted to present the periodic table in their works. Students preferred presented the periodic table as group of the valance orbital as Figure 4.10.

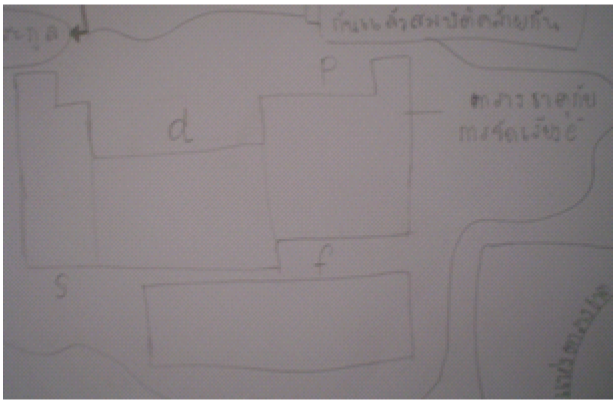



**Figure 4.10** The periodic table

Unlike the study of atomic structure, the video clips animation of the discovery about the periodic table was not include in the instructional unit. The finding revealed that most students were unable to explain the study of scientists. They answered were static, not explain a process of the study as they did with the studies of atomic structure which had video clips e.g. Newland used Octave law. The visual analogy found in this topic was name of the periodic table which represent method use of the science such as 'helical graphic', 'set of three elements', etc.

There were some students demonstrate alternative understanding of the periodic table indicated the elements under the zigzag line were transition elements (see Figure 4.11).

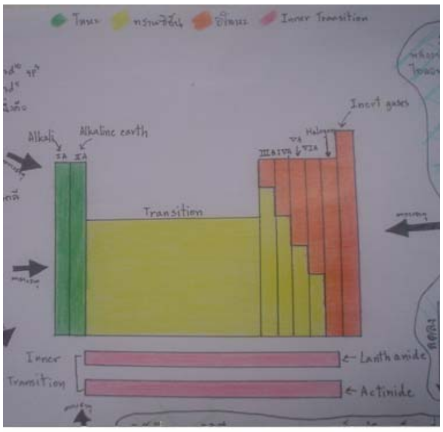



**Figure 4.11** Alternative periodic table

However, almost all students of school A held high visuospatial ability in the concept of position of element in the periodic table. They were able to indicate position of metals (included inner/outer transition elements), nonmetals, and metalloids in the periodic table using their own mental image of the periodic table. The example is following in the interview dialogue of a student and the researcher.

> R: Could you indicate the position of the periodic table? (without the periodic table)
>
> S: Yes, (I) use the ladder (zigzag line) as an indicator. The metals are on the left hand side and nonmetals are in the right hand side. The metalloids are on the border.

### 4.2.2 The Chemical Periodicity of the Elements

There was found an obvious relationship between student's spatial ability and their conceptual understanding of the chemical periodicity of the elements concept. The interview result indicated that the students who held sound understanding for the concept tended to draw preliminary figure of trend of elements' properties in the periodic table to answer the questions (see Figure 4.12), where as students who were unable to answer the questions draw fewer figures and were more likely to have incorrect drawing with inappropriate properties' trends.

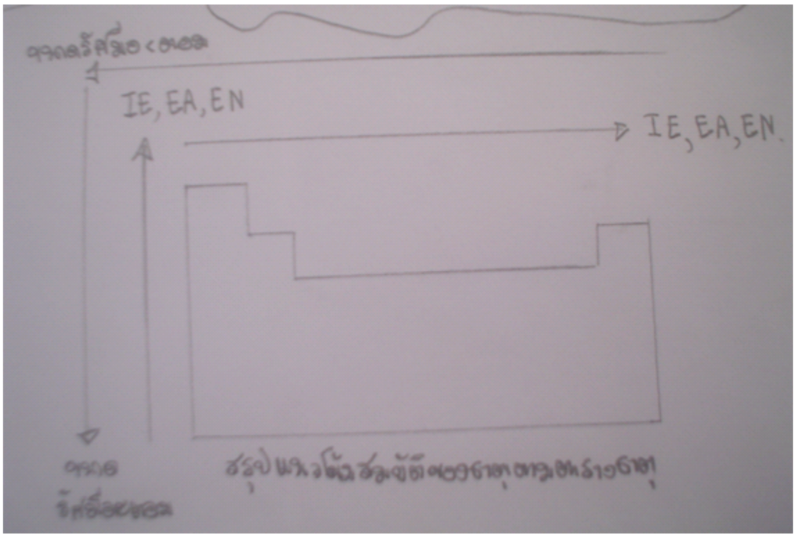



**Figure 4.12** Chemical periodicity of the elements

Moreover, students drew figure demonstrated the chemical processes phenomena along with the explanation of concepts e.g. ionization (see Figure 4.13). However, students were able to draw only figure of the processes contained in the video clips, even though those processes were included in the chemistry textbook. Again, this could be inferred again the video clips animations effected to student's visuospatial ability.

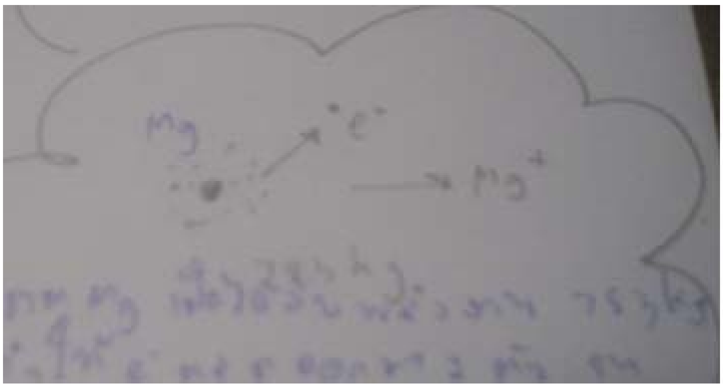


**Figure 4.13** The ionization process

Besides this, the strong relationship of student visualization of atomic radii and the understanding of ionization energy and electronegativity were found. Students often referred to atomic radii during explain those concepts. As well graph diagram of properties trend were also used for explain chemical periodicity of the elements (see Figure 4.14).

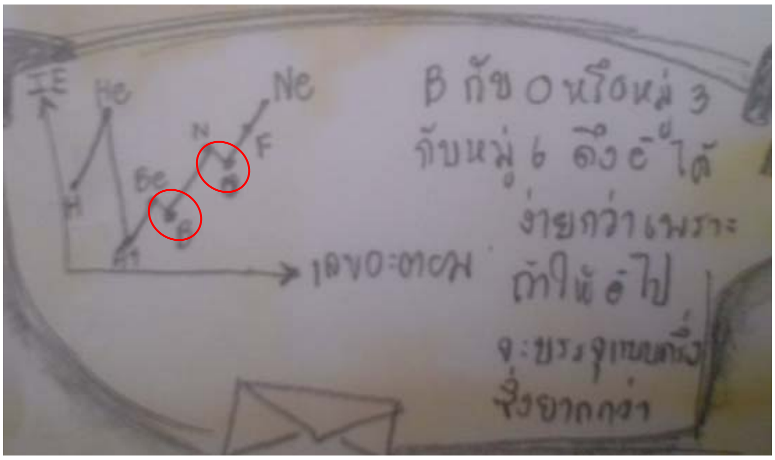



**Figure 4.14** Trend of ionization energy

**5. Student Perspective of the Atomic Structure and the Periodic Table Instructional Units Using Visuospatial Models**

The study discusses the results form the atomic structure and the periodic table instruction questionnaire (see appendix B) for each of the participant schools. Students' perspective of understanding level of concepts in atomic structure and the periodic table along with perspective of using video clips and VAST-models in learning concepts in atomic structure and the periodic table will be described.

The questionnaire recovery percentage of school A is 81% (36/44). All of participant students were female. Most of them (58%) received grade 4.00 in chemistry in semester 2/2548, the semester before conducting the research. This was followed by grade 3.50 (17%), grade 3.00 (11%), grade 2.50 (3%) respectively. None of them received a chemistry grade in semester 2/2548 lower than grade 2.50.

## 5.1 Students' Perspective of Understanding Level of Concepts in Atomic Structure and the Periodic Table

The participant students' perceptions of learning concepts in atomic structure and the periodic table regarding their perspective of understanding level respect to each concept is provided in Table 4.3. More than 50% of the participant students indicated that they were knowledgeable in almost all concepts, only the concept of nuclear symbol and mass number which were rated knowledgeable by only 36% of the students. The concept which the participant students felt very knowledgeable in highest percentage was isotope, 56%. The concepts that students felt little knowledge in highest percentage were atomic spectrum and energy calculation, and quantum numbers and orbitals, 36% and 31% respectively. The concepts of atomic spectrum and energy calculation, and trend of eletronegativity in the periodic table were highest mentioned of confusing, 8%.

The results indicated that the concepts which the participant students from school A felt that they were not knowledgeable were concepts relevance to calculation. For example the concept of atomic mass and the concept of atomic spectrum which students mentioned at low percentage in category very knowledgeable and high percentage in category confused. Other concepts were concepts relevance to the chemical periodicity trends of the elements for example ionization energy, electronegativity, electron affinity, melting point and boiling point, and oxidation numbers. Especially, the concept of electronegativity was mentioned in highest percentage of confusion. Only the concept of atomic size was mentioned to no confusion.

**Table 4.3** School A students perspective of understanding level of concepts in atomic structure and the periodic table.

| Topics | Concepts | Level of Understanding (% frequency) | | | |
|---|---|---|---|---|---|
| | | **Very Knowledgeable** | **Knowledgeable** | **Little Knowledge** | **Confused** |
| Atomic Structure | History of atomic structure study | 36 | 64 | 0 | 0 |
| | Properties of sub atomic particles | 25 | 69 | 3 | 0 |
| | Nuclear symbol, atomic number, and mass number | 69 | 31 | 0 | 0 |
| | Isotope | 56 | 36 | 6 | 0 |
| | Atomic mass and calculation | 22 | 64 | 6 | 8 |
| | Atomic spectrum and energy calculation | 8 | 50 | 36 | 6 |
| | Quantum numbers and orbitals | 14 | 53 | 31 | 3 |
| | Electron configurations | 42 | 50 | 8 | 0 |
| The Periodic Table | The development of the periodic table | 25 | 72 | 3 | 0 |
| | The arrangement of element into the periodic table | 33 | 56 | 3 | 6 |
| | Trend of atomic size in the periodic table | 33 | 61 | 3 | 0 |
| | Trend of ionization energy in the periodic table | 19 | 67 | 11 | 3 |
| | Trend of electronegativity in the periodic table | 14 | 58 | 19 | 8 |
| | Trend of electron affinity in the periodic table | 8 | 61 | 22 | 6 |
| | Trend of melting and boiling point in the periodic table | 8 | 61 | 25 | 6 |
| | Trend of oxidation numbers in the periodic table | 22 | 58 | 17 | 3 |

The examination of correlation between chemistry grade of participant students in the previous semester (2/2548) and their perspective of understanding level of concepts in atomic structure and the periodic table used Pearson product moment correlation coefficient at the level of significant .05. The correlation result showed that the chemistry grade of the participant students from school A effected to their perspective of understanding concept of history of atomic structure study, atomic mass and calculation, atomic spectrum and energy calculation, and trend of electronegativity in the periodic table. The Pearson product moment correlation coefficient value is showed in Table 4.4.

**Table 4.4** Correlation between chemistry grade of the participant students in semester 2/2548 and their perspective of understanding level of concepts in atomic structure and the periodic table of school A students.

| **Topics** | **Concepts** | **r** |
|---|---|---|
| Atomic Structure | History of atomic structure study | 0.38* |
| | Properties of sub atomic particles | 0.10 |
| | Nuclear symbol, atomic number, and mass number | -0.11 |
| | Isotope | 2.72 |
| | Atomic mass and calculation | 0.40* |
| | Atomic spectrum and energy calculation | 0.57* |
| | Quantum numbers and orbitals | 0.82 |
| | Electron configurations | 0.05 |
| The Periodic table | The development of the periodic table | -0.08 |
| | The arrangement of element into the periodic table | 0.15 |
| | Trend of atomic size in the periodic table | 0.26 |
| | Trend of ionization energy in the periodic table | 0.25 |
| | Trend of electronegativity in the periodic table | 0.37* |
| | Trend of electron affinity in the periodic table | 0.21 |
| | Trend of melting and boiling point in the periodic table | 0.08 |
| | Trend of oxidation numbers in the periodic table | 0.08 |

$p < .05$

## 5.2 Students' Perspective of Using Video Clips in Learning Atomic Structure and the Periodic Table

Perceptions of the participant students regarded to perspective of using video clips for learning concepts in atomic structure and the periodic table are summarized in Table 4.5.

**Table 4.5** School A students' perspective of using video clips for learning concepts in atomic structure and the periodic table.

| Video Clips | Using Video clips (% frequency) | | |
|---|---|---|---|
| | Very Helpful | Helpful | Not Helpful |
| Thomson's experiment | 58 | 39 | 3 |
| Milligan's experiment | 39 | 50 | 11 |
| Rutherford's experiment | 81 | 19 | 0 |
| The electron cloud model, and Bohr's model of atomic structure | 33 | 61 | 6 |
| Excited electron and electronic spectrum | 14 | 64 | 22 |
| Ionization of elements | 22 | 53 | 25 |
| Electron affinity of negative electrons | 11 | 75 | 11 |

The participant students from school A felt that all of video clips are helpful for their learning concepts in atomic structure and the periodic table. They mentioned that the video clip of Rutherford's experiment were very helpful, 81%, as well as the video clip of Thomson's experiment, 58%. The video clips which students mentioned to not helpful were video clip of the ionization of elements and the video clip of excited electrons and electronic spectrum, 25% and 22% respectively.

The participant students mentioned to benefits of using the video clips in learning concepts of atomic structure and the periodic table that video clips helped them to visualize abstract concepts (25%), made the concepts understandable more than reading or verbal description (39%), made lessons interesting (3%), helped to focus on lessons (3%), helped to remember contents (3%), given clear explanation of concepts (3%), and helped to follow up teacher's explanations (3%). However, students did mention to weaknesses of the video clips that the video clips were too fast (14%), the sound was not clear (8%), the video clips were too short (6%), and the vocabulary used in the video clips hard to make understanding (3%). Some of students (3%) suggested that the video clips should be provided for all concepts for better learning.

The correlation between chemistry grade of the participant students from school A in semester 2/2548 and using video clips for learning concepts in atomic structure and the periodic table indicated that there was no correlation between chemistry grade of the participant students and their perspective of using video clips for learning concepts in atomic structure and the periodic table. The Pearson product moment correlation coefficient value at the level of significant .05 is provided in Table 4.6.

**Table 4.6** Correlation between the participant students' chemistry grade in semester 2/2548 and their perspective of using video clips for learning concepts in atomic structure and the periodic table of school A students.

| **Video Clips** | **r** |
|---|---|
| Thomson's experiment | 0.13 |
| Milligan's experiment | 0.02 |
| Rutherford's experiment | 0.03 |
| The electron cloud model VS Bohr's model of atomic structure | -0.08 |
| Excited electron and electronic spectrum | 0.00 |
| Ionization of elements | 0.08 |
| Electron affinity of negative electrons | -0.12 |

### 5.3. Students' Perspective of Using VAST-models in Learning Atomic Structure and the Periodic Table

Students' perspective of using VAST-models respected to learning concepts in atomic structure and the periodic table is revealed in Table 4.7.

**Table 4.7** School A students' perspective of using VAST-models for learning concepts in atomic structure and the periodic table.

| Concepts | Using VAST-models (% frequency) | | |
|---|---|---|---|
| | **Very Helpful** | **Helpful** | **Not Helpful** |
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | 61 | 33 | 6 |
| Electron configurations | 64 | 36 | 0 |
| Isotopes | 36 | 53 | 11 |
| Arrangement elements into the periodic table | 36 | 53 | 11 |

Most of participant students mentioned that the VAST-models are very helpful for learning concepts in atomic structure and the periodic table, especially concept of electron configurations (64%) and concepts of atomic orbital's shapes and the arrangement of atomic orbitals in atom (61%). However, some of students mentioned that the VAST-models did not helpful for learning concept of isotope (11%) and concept of arrangement elements into the periodic table (11%).

Students explained that the VAST-models were helpful because they helped to visualized abstract concepts (19%), helped to make understanding about electron configurations (17%), helped to make understanding of atomic structure and position of orbitals in atom (14%), and made concepts understandable more than reading or verbal description (14%). More over, some of the participant students indicated they like the VAST-Modes because they can use them for self study (8%), the VAST-models encouraged their learning (3%), and make lessons fun and interesting (3%). Nevertheless, the VAST-models were mentioned that they were difficult for students to make understanding (3%) and sometimes they made students confuse (3%).

The Pearson product moment correlation coefficient at the level of significant .05 revealed no relation between chemistry grade of the participant students from school A in semester 2/2548 and the using VAST-models for learning concepts in atomic structure and the periodic table. The data is provided in Table 4.8.

**Table 4.8** Correlation between chemistry grade of the participant students in semester 2/2548 and their perspective of using VAST-models for learning concepts in atomic structure and the periodic table of school A students.

| **Concepts** | **r** |
|---|---|
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | -0.03 |
| Electron configurations | -0.11 |
| Isotopes | 0.20 |
| Arrangement elements into the periodic table | 0.10 |

**School B**

## 1. The Classroom Practice: Teacher Teaching and Students Learning by the Instructional Units Using Visuospatial Models

### 1.1 Classroom setting

The classroom was used by the case study class consist of 8 tables set in three table in the left hand side and middle row, and another two table are on the right hand side (See Figure 4.15).

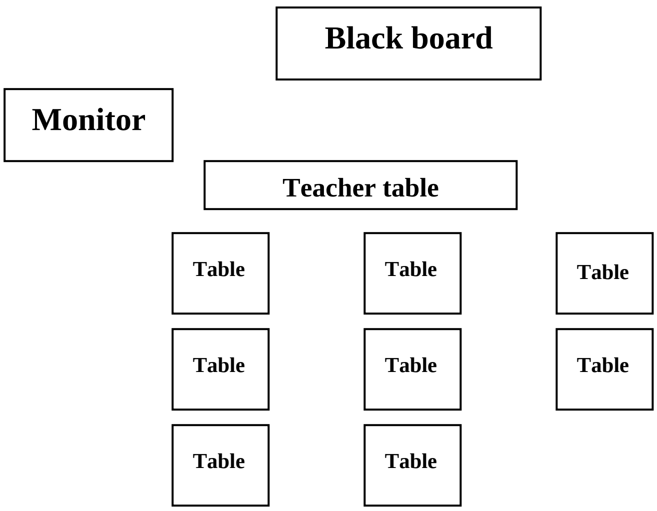



**Figure 4.15** A classroom setting of school B

The groups of students were changed only one time at the early of the semester. The teacher gave a reason for group changing that separated students from their close friend group to help them concentrate on learning rather than talk to each other.

## 1.2 The Classroom Practice: Teacher Teaching and Student Learning by the Instructional Units Using Visuospatial Models

### 1.2.1 Visuospatial Models and the Classroom Discussion

Similarly to Jandra's class, Chuchart mostly started the units by asking questions to require students' existing knowledge. However Chuchart emphasized asking concept which have taught the previous periods whether those concepts related to the concept he intended to teach or not e.g. asked concept about nuclear symbol and isotope in teaching wave properties and electromagnetic radiation of atomic spectra. Fortunately, almost every concepts in atomic structure and the periodic table are related. The visuospatial models or worksheets, sometime he explained those visuospatial models and worksheets before the discussion. This was because Chuchart afraid that student's may not have knowledge enough for the discussion.

> "Some video clips are needed explanation. I have to add more detail to make them sound understanding for students"

> "If the worksheets have enough information likes the worksheet 'Isotope' students are ready for the discussion".

The experiment discussions were depended on an available time the class had. The teacher requested every group presented their works rather raised questions for discussion. Therefore the time run out before the discussion began. On the other hand, the video discussions were often. Students had a chance to interpret, give a causal explanation, and predict about the phenomenon represented by the video clips.

After presented the video clip of the first ionization energy of Magnesium, Chuchart: "What do you think the first ionization energy of the second electron will more or less than of the first electron?...Umm…A

A: It's will be greater, isn't it ?

Chuchart: I don't know. Who can help A?

Chuchart: O.K.  B, what should happen?

B: I think the second ionization always greater because cation is smaller than the neutral atom.

**Figure 4.16** Teacher's demonstration

Once interesting question about the VAST-models raised by a student after the teacher demonstrated a quantum mechanical model of atom (electron cloud model), how to orders atomic orbitals in each electron energy level and fill electron in each atomic orbital.

Student 1: Teacher, why do you fill *s*-orbital at the last? In Aufbau's order, *s*-orbital is the first orbital in each energy level though.

Chuchart: Any body else could help me explain?

The class was still, no one could answer the question. This situation was very special, at the moment every students in the class were listening and waiting for the explanation. The teacher explained that;

"Compared to other atomic orbitals in the same energy level *s*-orbital is biggest, so it cover the others"

A student's questions for some reason stimulated classroom thinking well than questions raised by the teacher.

### 1.2.2 Visuospatial Model and the Experiment

Since the experiments in the topics of atomic structure and the periodic table could not set in a high school laboratory because a limitation of scientific instruments. Therefore most of the experiments were in the video clips.

However, there were also two experiments which Chuchart determined to choose the visuospatial models video clips and the VAST-models involved; "Flame Test" and "VAST-models and Structure of the Elements".

Concerning the Flame Test experiment, Chuchart selected the video clip "State of Electron According to Bohr's Atomic Model". For detailing students of the experimental result, the video clip revealed students what is happening in atom of the burnt element. Here students were had a chance to compare what they have seen as macroscopic level of representation flames colors and the microscopic level of representation of phenomenon in excited atom from the video clip. Nevertheless, again the time were run out and students had no time for discussion.

Regards the activity "VAST-models and Structure of the Elements", students were fully hands-on and mind-on working with the VAST-models. Each groups of students were selected their own element, included atom, ions, or isotopes. Subsequently, passed their model to the other groups, asked them to interpret model of the element; electron configuration, number of electron, number of protons, number of neutrons, isotope, name of element, and symbol of the element. At the end of the activity each group had to give an answer of their model. Everyone in the class then evaluated the model construction of their friends and also checked their understanding in the same time.

## 2. Student Understanding of Concepts in Atomic Structure

All 42 participant students were again examined their understanding of concepts in atomic structure. The numbers and percentages of given answers of school B students is showed in Table 4.9. The student answers are discussed following the main concepts in atomic structure and the periodic table as below.

**Table 4.9** Numbers and percentages of given answer for the questions about atomic structure of school B students.

| **Concepts** | **Question No.** | **SU** | | **PU** | | **AU** | | **NU** | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** |
| Model | 1 | 15 | 36 | 0 | 0 | 26 | 62 | 1 | 2 |
| Properties of sub atomic particles | 2 | 25 | 60 | 14 | 33 | 3 | 7 | 0 | 0 |
| | 3 | 27 | 64 | 6 | 14 | 7 | 17 | 2 | 5 |
| | 4 | 2 | 5 | 15 | 36 | 1 | 2 | 24 | 57 |
| Atomic model | 5 | 11 | 26 | 0 | 0 | 10 | 24 | 20 | 48 |
| | 6 | 9 | 21 | 33 | 79 | 0 | 0 | 0 | 0 |
| Atomic number, atomic mass, and nuclear symbol | 7 | 16 | 38 | 21 | 50 | 0 | 0 | 4 | 10 |
| | 8 | 24 | 57 | 10 | 24 | 0 | 0 | 8 | 19 |
| | 9 | 29 | 69 | 4 | 10 | 0 | 0 | 9 | 21 |
| | 11 | 23 | 55 | 0 | 0 | 10 | 24 | 9 | 21 |
| Isotope and atomic mass | 10 | 17 | 41 | 4 | 10 | 4 | 10 | 17 | 40 |
| | 12 | 19 | 45 | 0 | 0 | 12 | 29 | 4 | 10 |
| | 13 | 16 | 38 | 12 | 29 | 0 | 0 | 14 | 33 |
| Wave properties of atom and atomic spectra | 14 | 22 | 52 | 10 | 24 | 0 | 0 | 10 | 24 |
| | 15 | 10 | 24 | 11 | 26 | 1 | 2 | 20 | 48 |
| Atomic orbitals and electron configurations | 16 | 35 | 83 | 0 | 0 | 1 | 2 | 6 | 14 |
| | 17 | 26 | 62 | 6 | 14 | 6 | 14 | 4 | 10 |
| | 18 | 20 | 48 | 2 | 5 | 17 | 41 | 3 | 7 |
| | 19 | 13 | 31 | 20 | 48 | 6 | 14 | 3 | 7 |

SU = sound understanding, PU = partial understanding, AU = specific alternative understanding, NU = no understanding.

### 2.1 Model

Students were required their conception about model. Fifteen students (36%) held sound understanding stated the verbal statement of Democritus's atomic theory is a model. Most of the students (26 students, 62%) held alternative understandings. The alternative understandings found were; verbal statement is not a model (18 students, 43%), a model needs experimental result supported (6 students, 14%), and models are only in a concrete form (2 students, 5%).

### 2.2 Properties of Sub Atomic Particles

Students were asked to specify the properties of protons, electrons, and neutrons. The possible direction of protons in the cathode tube was asked. Most students (25 students, 58%) held sound understanding that protons hold positively charge and move toward the cathode which has negatively charge. The partial understandings immerged was students correctly stated that protons hold positively charge, however, remained with problems of understanding and confusion about charges of electrodes (2 students, 5%), electric attraction/repulsion of proton and the electrodes (6 students, 14%) and both (6 students, 14%). There was three students (7%) held alternative understanding, stated that protons hold negatively charge and move toward anode which has positively charge.

Students were explored concept of properties of cathode rays (electron), required understanding about Thomson's experiment and the conclusion he claimed. Most of the students (27 students, 64%) held sound understanding that Thomson made a conclusion that cathode rays have negatively charge because they were attracted by anode which has positively charge. The partial understanding found was cathode rays hold negatively charges because they were deflected by electric field and magnetic field (6 students, 14%). Actually not only electron (cathode rays) was deflected by electric and magnetic fields but also proton, so this could not be the reason claimed for the charge of electron. Alternative understandings found were again about electrodes and their attraction/repulsion; cathode rays hold positively charge and were attracted by negatively charge cathode (3 students, 7%), cathode rays hold positively charge and were deflected by magnetic and electric fields (2 students, 5%), and negative cathode rays were attract by negative cathode plate (2 students, 5%).

In addition, students were asked to predict result of shooting $\alpha$-particles into atomic nucleus. Only two students (5%) held sound understanding that α-particles will return from the gold foil in the same direction from which they had come because both nucleus and $\alpha$-particle held high positively charge. Fifteen students (36%) held partial understanding stated that α-particles will return in the same direction they had come because of massive nucleus. The alternative understanding found was high positively charge α-particles passed through the nucleus with no deflection because nucleus held on charge (1 student, 2%).

### 2.3 Atomic Models

Students were asked to ascertain the Rutherford's gold foil experiment. Eleven students (26%) held sound understanding. They correctly stated that most of α-particles passed through the gold foil with little or no deflection because most of atomic area is empty space. There was no partial understanding found, however, two alternative understandings were occurred. The alternative understanding found was most of α-particles passed through the foil would have been deflected at very small angles because the positively charge protons scattered thoroughly an atom (8 students, 19%), this could inferred that these students held the plum pudding atomic model of Thomson. Another alternative understanding found was most of $\alpha$-particles were deflected at large angles because they hit the positively charge particles in the nucleus (2 student, 5%). This could be inferred that students did not focus on the entire atom, only focused on the atomic nucleus.

Not only that, students were further required their mental model of atom. There were three different students' mental models were found. Unfortunately, only nine students (21%) held the scientific model of atom, a quantum mechanical model of atom which referred to probability to find electrons within a certain volume of space surrounding the nucleus. Most of the students (17 students, 41%) held Thomson's atomic model stated that electrons stuck into a lump of protons thoroughly the atom. Bohr's atomic model of atom was found with sixteen students (38%), stated that electrons traveled in a particular path as fixed energy level.

### 2.4 Atomic Number, Mass Number and Nuclear Symbol

Students were asked to define atomic number. Sixteen students (38%) held sound understanding: atomic number is the number of proton in atom, losing or gaining proton cause element changed. Half of students (21 students, 50%) held partial understanding, stated that atomic number is the number of electron because elements always hold the same number of protons and electrons. However, this answer is correct only with the atom not including ions of the element, only neutral atom has equal number of protons and electrons.

For concept of atomic mass, Most of the students (24 students, 57%) held sound understanding that mass number is the sum of protons number and neutrons number in an atom. They gave a reason, to not included electron number, because mass of electron is very less compared to mass of protons and neutron. The partial understandings found in the reasons students gave to explain their answer; the number of electrons not combine to the mass number because could not accurate mass of the moving electrons (8 students, 19%) and electrons had no mass (2 students, 5%).

Students were also asked to interpret nuclear symbol of the element which has 18 electrons. Most of the students (29 students, 69%) held sound understanding that the nuclear symbol of the element is ${}^{40}_{18}Ar$ . The explanation was that the element which has electron 19 particles, the atomic number will be 18. The element was Argon. Argon has 22 neutrons so the atomic mass of Argon is 40. To write nuclear symbol of elements, atomic number is as a subscript in the lower left corner and the mass number as a superscript in the upper left corner. The partial understanding found was students able to indicate atomic number and mass number of the atom. However, they confused the location of atomic number and atomic mass, placed atomic number at superscript and atomic mass at subscript (1 student, 2%), and even students was able to indicate the atomic number, they still mentioned that the information was not enough to not indicate the element (3 students, 7%).

About the nuclear symbol, students were also asked to find out proton number of $S^{2-}$. Most of the students (23 students, 55%) held sound understanding, indicated that $S^{2-}$ had 16 protons, mentioned that proton numbers of any element would never change. Alternative understanding found was $S^{2-}$ had 18 protons because Sulfur (S) gained 2 electrons and the gaining electrons effected to number of electron because number of protons and electrons in any element are always the same (10 students, 24%).

### 2.5 Isotope and Atomic Mass

Students' understanding of isotope was explored. They were asked to determine the different between ${}_{6}X$ and ${}^{12}C$. Most of the students (17 students, 41%) held sound understanding, indicated that both elements were carbon. The partial understanding found with four students (10%). They correctly mentioned isotopes are the same element which consists of different masses. Nevertheless, they mentioned that X may be not Carbon. This could be inferred that students did not concern that isotopes of an element hold the same atomic number. Alternative understanding found was ${}_{6}X$ and ${}^{12}C$ were not the same element, they stated that even ${}_{6}X$ and ${}^{12}C$ were isotopes but the element X could be the others element which is not Carbon (4 students, 10%). This could interpret that again even students knew the definition of isotope but they did not really understand the meaning of it.

In the concept of atomic mass, students were asked to predict amount of the two isotopes, Cu-63 and Cu-65, of Copper in the nature. Most of the students (19 students, 45%) held sound understanding, stated that an isotope which has mass number closer to atomic mass of the element (Cu-63) found more in the nature because atomic mass is a weight average of isotopes of the element (Cu = 63.55 amu.). The alternative understandings found was the massive isotope (Cu-65) is easier to find in the nature because it is bigger (7 students, 17%). Moreover, even mass of the two isotopes were gave, students still mentioned they did not have enough information for the diagnosis (12 students, 29%). This could be indicated that these students did not gain the concept of atomic mass.

Students were in depth explored their understanding of atomic mass. They were asked to calculate atomic mass of element (Boron) form its isotopes (B-10 and B-11). Most of the students (16 students, 38%) held sound understanding. Students were able to calculate atomic mass from weight average of isotopic abundances. Twelve students (29%) held partial understandings; eight students (19%) were able in the calculation but did not use specific unit of atomic mass, amu., and four students (10%) were able to indicate the formula: atomic mass = atomic number of isotope x abundant percentage of the isotope +…, but did not show the calculation process.

### 2.6 Wave Properties of Atom and Atomic Spectra

Students were asked to calculate the wavelength of yellow light. More than half of students (22 students, 52%) held sound understanding for the concept: used the proper formula to solve the problem and successful in calculation. The partial understanding found were; students were successful in calculation process but did not specify the formula used in the calculation (2 students, 5%), and students indicate the specific formula: $\lambda = \frac{c}{\upsilon}$, where $\lambda$ was wavelength of the yellow light, $c$ was the speed of light, and $\upsilon$ was frequency of the yellow light but did not show the problem solving (8 students, 19%).

Further more, students were required to calculate quantum energy. There were nearly half students (20 students, 48%) did not answer this question. Ten students (24%) of the students who answered the question held sound understanding; used proper formula to solve the problem ($E = \frac{hc}{\lambda}$, where $E$ was quantum energy, $c$ was the speed of light, and $\lambda$ was a wavelength), correctly conversed the unit (angstrom to meter), and did correctly problem solving. Other eleven students (26%) held partial understandings; eight students (19%) were able to indicate the formula but did not show the calculation, one student (2%) was able to use the proper formula and showed the correct problem solving but could not change the specific unit, another one student (2%) was also able to use the proper formula and able to change unit but the answers they gave was not correct, and one student (2%) used the proper formula but did not change the specific unit before doing the calculation. The alternative concept found was student use improper formula and did not change unit in calculation (1 student, 2%).

### 2.7 Atomic Orbitals and Electron Configuration

Students were asked to demonstrate electron configurations of the element. Most of the students (35 students, 83%) held sound understanding for the concept, provided different method used for the electron configurations. More than half of students (25 students, 60%) were able to use both Aufbau's diagram and the periodic table (noble gas). Six students (14%) used only the periodic table and four students (10%) used only Aufbau's diagram for electron configuration. The alternative understanding found was student not able to use the periodic table for electron configuration and made a mistake with the order of electron energy level in Afbau's diagram (1 student, 2%).

In addition, students were also asked to consider the given electron configuration, required students' reason for electrons' behavior. Most of the students held sound understandings for the concept: electrons were fulfilled the lowest energy level before enter the next energy levels (26 students, 62%), electrons tried arrange as half-filled or filled set of orbitals to enhance stability of the element (20 students, 48%), and the large energy gap between *3s*- and *3p*-orbitals effected to electron transferring between them, even for half-filled or filled set arrangement (13 students, 31%). The partial understandings found in different cases. Six students (14%) were able to use Aufbau's diagram but confused about an order of orbitals in electron configuration, indicated that [Ar] $3d^{10}4s^{1}4p^{6}$ and [Ar] $4s^{1}3d^{10}4p^{6}$ were different. Two students (5%) correctly indicated the electron configuration of the given transition element (Cr = [Ar] $4s^{1}3d^{5}$). However their explanation for electron skipping was not quite right, addressed the orbital overlapping of *ns* and (*n*-1)*d* orbitals but did not address to stability enhancing.

The alternative understandings found for the concept were; electrons in different orbitals at the same energy level could be shifted to each other orbitals e.g. electron in *4s*-orbital and *4p*-orbital (6 students, 14%), electron shifting only occurred with complicated orbitals (1 student, 2%), the shifting $4s^{2}$ to $3d^{4}$ to make a half-filled electron arrangement [Ar] $4s^{2}3d^{4}$ will never happen because there were no exception for the tough rule of Aufbau order (17 students, 41%). Moreover, there were also numerous students attentive to enhance stability until missed concern the gap between *3s*-orbital and *3p*-orbital, stated that electrons form *3s* could move to *3p* for half-filled arrangement of the electron configuration (20 students, 48%).

### 3. Student Understanding of Concepts in the Periodic Table

All 42 participants of school B students were again examined for their understanding of concepts in the periodic table. Numbers and percentages of given answers of each question is shown in Table 4.10. The results of student understandings are discussed following the main concepts in the periodic table as below.

**Table 4.10** Numbers and percentages of given answer for the questions about the periodic table of school B students.

| Concepts | Question No. | SU | | PU | | AU | | NU | |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | *%* | *n* | *%* | *n* | *%* | *n* | *%* |
| The periodic table and electron configuration | 20 | 27 | 64 | 0 | 0 | 0 | 0 | 15 | 36 |
| Chemical properties and a physical properties of metals, nonmetals, and metalloids | 21 | 23 | 55 | 10 | 24 | 6 | 14 | 3 | 7 |
| | 22 | 16 | 38 | 3 | 7 | 20 | 48 | 3 | 7 |
| | 23 | 31 | 74 | 9 | 21 | 0 | 0 | 2 | 5 |
| | 24 | 8 | 19 | 4 | 10 | 4 | 10 | 26 | 62 |
| | 25 | 21 | 50 | 0 | 0 | 17 | 40 | 4 | 10 |
| | 26 | 21 | 50 | 0 | 0 | 6 | 14 | 14 | 34 |
| Atomic radii | 27 | 18 | 43 | 0 | 0 | 18 | 43 | 6 | 14 |
| Ionization energy | 28 | 27 | 64 | 0 | 0 | 1 | 2 | 14 | 33 |
| | 29 | 25 | 60 | 1 | 2 | 3 | 7 | 13 | 31 |
| | 31 | 4 | 10 | 19 | 45 | 0 | 0 | 19 | 45 |
| | 32 | 13 | 31 | 18 | 43 | 0 | 0 | 11 | 26 |
| Ionic radii | 30 | 8 | 19 | 17 | 41 | 3 | 7 | 14 | 33 |
| Electronegativity | 33 | 9 | 21 | 0 | 0 | 8 | 19 | 25 | 60 |
| | 34 | 3 | 7 | 28 | 66 | 0 | 0 | 11 | 26 |
| Electron affinity | 35 | 6 | 14 | 0 | 0 | 29 | 69 | 7 | 17 |
| | 36 | 21 | 50 | 0 | 0 | 14 | 29 | 0 | 0 |
| Melting point and boiling point | 37 | 20 | 48 | 6 | 14 | 7 | 17 | 9 | 21 |
| | 38 | 32 | 76 | 6 | 14 | 0 | 0 | 4 | 10 |
| Oxidation number | 39 | 22 | 52 | 0 | 0 | 5 | 12 | 15 | 36 |
| | 40 | 29 | 69 | 0 | 0 | 10 | 24 | 3 | 7 |

SU = sound understanding, PU = partial understanding, AU = alternative understanding, NU = no understanding.

### 3.1 The Periodic Table and Electron Configuration

Students were asked to specify group and period in the periodic table of the element. Many students who answered the question (27 students, 64%) held sound understandings. They used proper, but different methods of electron configuration to solve the problem and correctly stated that the outer most energy level indicated period, and valence electron indicated the group of the element. The methods used for electron configuration of the element found were; the periodic table (noble gas) (9 students 21%), Bohr's diagram (7 students, 17%), Aufbau's diagram (4 students, 10%), Aufbau's diagram and Bohr's diagram (4 students, 10%), the periodic table and

Aufbau's diagram (1 student, 2%), and used all different methods: the periodic table, Aufbau's diagram, and Bohr's diagram (2 students, 5%).

### 3.2 Chemical Periodicity of Elements

The eight concepts of chemical periodicity of element were explored; (1) chemical and physical properties of metals, nonmetals, and metalloids, (2) atomic radii, (3) ionization energy, (4) ionic radii, (5) electronegativity, (6) electron affinity, (7) melting point and boiling point, and (8) oxidation number.

#### 3.2.1 Chemical and Physical Properties of Metals, Nonmetals, and Metalloids

Students were asked to compare stability of atoms and ions. They were asked to compare stability of Zinc and Rhodium as well as Sulfur atom or Sulfur ion ($S^{2-}$). Most of the students held sound understandings for the concept; Zinc is more stable than Rhodium (23 students, 55%), and Sulfur ion is more stable than Sulfur atom (16 students, 38%) because they hold a filled arrangement of the electron configuration. The partial understandings found were; students correctly mention that transition elements held similar properties so they claimed the stability of Zinc and Rhodium were the same (10 students, 24%), and correctly indicated that Sulfur ion is more stable than Sulfur atom albeit the given reason was not reasonable, because Sulfur ion found in nature is more than Sulfur atom (3 students, 7%). The alternative understandings found were; bigger atom (Rhodium) is more stable (4 students, 10%), smaller atom (Zinc) is more stable (2 students, 5%), the half-filled electron configuration element is not stable (1 student, 2%), two extra electrons of sulfur ion cause electron repulsion so sulfur ion is less stable compared to sulfur atom (12 students, 29%), and both Sulfur atom and Sulfur ion are the same element so they hold equal stability (7 students, 17%).

Students were asked about malleable ability and ductile ability of metals. Three-fourths of students (31 students, 74%) held sound understanding that metals can be hammered into sheets and can be drawn into wires because mobile electrons of metallic bonding belong to the metallic crystal as whole. Partial understandings found for the concept were; only massive metal hold malleable ability and ductile ability (3 students 7%), and malleable ability and ductile ability of metals depend on their atomic size, only electrons of small atom able to mobilize through a whole metallic crystal, the big metal atoms could not (6 students, 14%).

Students were asked to indicate properties of the nonmetal elements. Only eight students (19%) held sound understanding: not all of nonmetal elements are gases, some of nonmetal elements are solids. Partial understanding emerged was nonmetal elements have low melting and boiling points so they were all gases (4 students, 10%). The alternative understandings found were; all covalent molecules were gases (3 students, 7%), and nonmetals were light compared to metals so they were able to float as gases (1 student, 2%).

Students were asked to predict conductivity of metalloids. Half of students (21 students, 50%) held sound understanding: the conductivity of the heated metalloid is getting better because their electrons are moving faster. The alternative understandings found were; the bonding of metalloids turn to metallic bonding at high energy level (4 students, 10%), and metalloids hold no conductivity because they all form covalent bonding and covalent molecules are insulators (13 students, 31%).

Additionally, students were required a reason consequence the high stability noble gases. Half of students (21 students, 50%) held sound understanding: the filled arrangement of the electron causes noble gases stable. The alternative understandings found were; the electric attraction force between protons and electrons in noble gases atoms, their highest number of electron and protons resulted highest attraction force, this cause them tend to not lose or share their electrons (4 students, 10%), and small size noble gases achieve strongest attraction force elements in the period so it's hard to lose electrons (2 students, 5%).

### 3.2.2 Atomic Radii

Students were asked to determine atomic radii from the given electron configuration. Most of the students (18 students, 43%) held sound understanding for the concept: atomic radii of the atom which has electron configuration $1s^2 2s^2 2p^6 3s^1$ is not the smallest atom of the period which it occupy. The smallest atom of each period was in group VIIA ($np^7$). Alternative understandings found with this concept were; group IA elements are the smallest elements compared to others elements in the same period (13 students, 31%), the orbital 3*s* filled two electrons so atom of $3s^1$ is smallest in the period (4 students, 10%), and atomic radii of elements could not predict by using electron configuration (1 student, 2%)

### 3.2.3 Ionization Energy

Students were asked to predict phenomena that take place in the ionized atoms. The sound understanding for the concept transpired were; the remaining ten electrons of the ionized sodium ion ($Na^+$) will experience greater attraction by the nucleus (27 students, 64%), the second ionization energy ($IE_2$) requires the removal of the second electron from Sodium ion ($Na^+$) is greater than the first ionization energy ($IE_1$) because the greater electric attraction force between the remaining electron and nucleus (11 students, 26%), the second electron of Sodium occupy in the energy level which closer to nucleus than the first electron (14 students, 33%), and ionization energy of positive ions were always greater compared to neutral atoms because their electric attraction force between protons and electrons was stronger (13 students, 31%). Partial understanding found were; the second ionization energy of Sodium was greater than the first ionization energy because the $Na^+$ ion tend to preserve its stable/noble gas configuration to sustain its stability (1 student, 2%), and the ionization energy of positive ions is always greater than the ionization energy of neutral atoms because the second electron occupied in the energy level closer to nucleus than the previous one (18 students, 43%). Nonetheless, this was not always true, because sometime the second electron is still in the same energy level as the first electron. The alternative understandings found were; the electron which is removed will take away the attraction of the nucleus with it when it leaves the atom (1 students, 2%), and $Na^+$ will never lose any more electron of its stable/noble gas configuration because this will reduce stability of it (3 students, 7%).

And also, students were asked to indicate ionization energy trend of Beryllium (Be), Boron (B), Nitrogen (N), and Oxygen (O). Only four students (10%) held sound understanding for the concept: the ionization energy trend is N>O>Be>Be and explained that the first ionization energy increase generally as moving from left to the right across a period of the periodic table. However, Boron and Oxygen rather lose their electron for their stable half-filled and filled electron configuration. This caused ionization energy dropped in Boron and Oxygen, so $IE_1$ of Beryllium is greater than $IE_1$ of Boron and $IE_1$ of Nitrogen is greater than $IE_1$ of Oxygen. The partial understandings found were; students were able to explain nature of ionization energy, $IE_1$ generally increase as moving from left to the right across a period of the periodic table (8 students, 19%), and $IE_1$ depended on size of atoms, the smaller atoms held greater $IE_1$ (11 students, 26%). However, as explained above, students did not concern the exception of Boron and Oxygen therefore stated that the trend of $IE_1$ is O>N>B>Be.

### 3.2.4 Ionic Radii

Students were required to compare ionic radii of Fluoride ion and Sodium ion. Only eight students (19%) held sound understanding. The sound understanding for the concept was the same electron configuration fluoride ion and sodium ion, fluoride ion is bigger because sodium ion contains more protons in its nucleus. There was again the partial understanding for the concept found at highest percentage (17 students, 41%). The partial understanding was negative ions are always bigger than positive ions. However, this statement could be used only for ions of the same element, cations (positive ions) of some element is bigger than anions (negative ions) of other elements e.g. ionic radii of Francium ion ($Fr^+$ = 194 pm) is greater than Chloride ion ($Cl^-$ = 181 pm). The alternative understandings found was

Fluoride ion and Sodium ion hold the same size because the have the same number of electron (3 students, 7%).

### 3.2.5 Electronegativity

Students were asked to order electronegativity of beryllium (Be), iron (Fe), germanium (Ge), and tellurium (Te). Only nine students (21%) held sound understanding for the concept: the order of electronegativity is Te>Ge>Fe>Be because electronegativities increase from left to right across period and decreased from top to bottom within group of the periodic table. Alternative understandings emerged nearly the same percentage with sound understanding. The alternative understanding was the biggest atom has greatest electronegativity (8 students, 19%).

Students were further in dept required their under standing of electronegativity, asked their expectation of Hydrogen (H) bond with Fluorine (F) forms Hydrogen fluoride molecule (HF). Only three students (7%) held sound understanding, stated that electron tendency is attracted to Fluorine because its electronegativity is greater than Hydrogen (HF is polar covalent molecule). More than half of students (28 students, 67%) held partial understandings. The partial understandings found were; electron tendency is in the middle of Hydrogen and Fluorine because HF is a covalent molecule, their electrons are sharing (16 students, 38%), and electron is attracted to fluorine because to form bonding, hydrogen lose an electron ($H^+$) and fluorine receive the electron ($F^-$) (12 students, 29%).

### 3.2.6 Electron Affinity

Students were asked to judge about electron affinity of metals. Only six students (14%) held sound understanding for the concept: electron affinities of metals are negative for the reason that to add an electron to metals to form anion, the reaction is exothermic. Nearly all of students (29 students, 69%) held alternative understandings. The alternative understandings found for this concept were; metals prefer to be cations therefore to form metal anions require energy to push electrons into atom (14 students, 33%), the sign positive (+) represent the used energy for exothermic reaction (8 students, 19%), the positive electron affinity is only use with the reaction for cation forming (5 students, 12%), and it is impossible to form metal anions (2 students, 5%).

Even Most of the students held alternative understanding for electron affinity of metals, when students were asked to interpret the equation of electron affinity, $K\ (g) + e^- \longrightarrow K^-\ (g) + 48\ kJ$, EA = -48 kJ/mol, Most of the students (21 students, 50%) held sound understanding for the concept. The sound understanding is to form potassium anion, potassium atom need to release the energy out because energy is required for electron free and energy is released for electron attachment. The alternative understandings found were; it is impossible to form potassium anions (11students, 26%), and the negative electron affinity of the equation express that used energy in this equation is less than zero (3 students, 7%).

### 3.2.7 Melting Point and Boiling Point

Students were asked to predict melting point and boiling point small size metals. Nearly half of students (20 students, 48%) held sound understanding for the concept: small size metals hold high melting point and boiling point because they close packed crystal requires high energy for breaking out. Partial understanding found was every metals have high melting point and boiling point (6 students, 14%), and small size metals have low melting point and boiling point because they are light so need not much energy to break them apart (7 students, 17 %).

More over, students were asked to consider melting point and boiling point of metals and nonmetals. Most of the students (32 students, 76%) held sound understanding that melting point and boiling point of metals were higher than nonmetals because metals bond of metals is stronger than covalent bond of nonmetal. Six students (14%) held partial understanding; two students (5%) stated that melting point and boiling point of metals is more than nonmetals because metals are solid whereas nonmetals are gases, and four students (10%) stated that melting point and boiling point of metals less than nonmetals because nonmetals in group VIA have highest melting point and boiling point.

#### 3.2.8 Oxidation Number

Students were asked to indicate oxidation number of sodium (Na) in sodium nitrate ($NaNO_3$). Most of the students (22 students, 52%) held sound understanding, stated that sodium has oxidation number +1 because elements in Group IA have oxidation number +1. The alternative understandings found were; oxidation number of element equal oxidation number of compounds which the element composed (2 students, 5%), and oxidation number of element atom is zero even in compounds (3 students, 7).

Students further enquired to compare oxidation number of Sulfur (S) in the Sulfuric acid ($H_2SO_4$) and Sulfur dioxide ($SO_2$). More than half of students (29 students, 69%) held sound understanding that oxidation number of S in the compounds is different, +6 in $H_2SO_4$ and +4 in $SO_2$. The explanation is each element hold vary oxidation number depends on compound it composed. Alternative understandings found were; the same element always hold the same oxidation number (5 students, 12%), oxidation number of S in $H_2SO_4$ and $SO_2$ are equal because both compounds contain one atom of sulfur the same (3 students, 7%), and again students still mention that oxidation number of elements atom is always zero even in compounds (2 students, 5%).

### 4. Student Visuospatial Thinking

All 42 students of school B were examined their visuospatial cognitive from the beginning through the end of the implementation of atomic structure and the periodic table instructional units. The data collected form concept mapping and classroom activities deal with the VAST-models, video clip animations, and narration text/lecture were demonstrated. Besides this six students from the class were interviewed at the end of the instructional units implementation. School B students' visuospatial thinking of atomic structure and the periodic table were described as the following.

## 4.1 Student Visuospatial Abilities on Atomic Structure

### 4.1.1 Atomic Models

There were two different atomic models represented in students' works in the concept of atomic structure, atomic models demonstrated by scientists and atomic model which students used to express any concepts. Students mentioned all of atomic models their works included atomic models of Democritus, Dalton, Thomson, Rutherford, Bohr and Schrödinger. There were two kind of models representation occurred, verbal explanations and figures. Albeit, the verbal statements were more preferable. It appeared that students hold image of atomic structure in their head and expressed out their mental images of atomic structure. Students' definition provided the consideration of visualization in communication.

> "…It's a sphere, contained positive particles and negative particles inside as the same number" (Thomson's atomic model).

Along with the representative figure, there was always at least a short statement explained the figure. The visual analogy was found in students communication of atomic models e.g. billiard ball (Dalton's), plum pudding (Thomson's), solar system (Bohr's), and cloud (quantum mechanical model). These visual analogies were the same which mentioned in the curriculum, however, students were reached the target atomic model using them.

There was also revealed the alternative atomic models. Students drew inappropriate structure for Bohr's atomic model, demonstrated electron energy levels as equal distant. However, students stated a statement "very for away" in the figure between the nucleus and the first energy level.

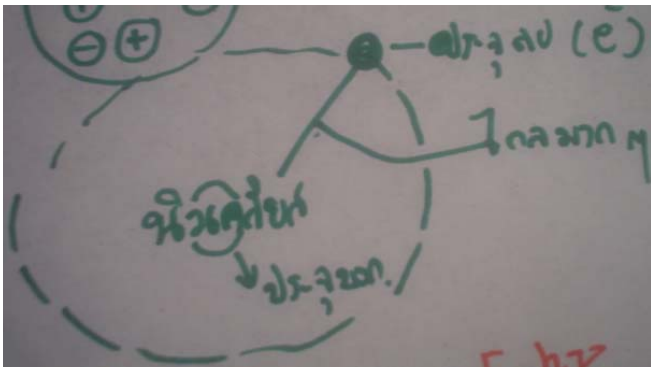


**Figure 4.17** Bohr's atomic model of school B student

In addition, the confusion between Rutherford's and Bohr's atomic models were found. Some students presented Rutherford's atomic model used energy levels likes the Bohr's.

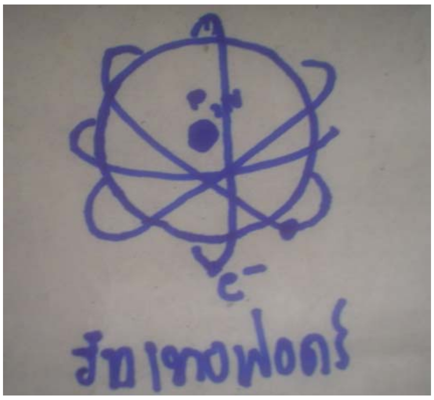


**Figure 4.18** Rutherford's atomic model

School B students held high spatial ability in quantum mechanical model of atomic structure. The two-dimensional figure of students was concerned the distance of electrons density from the nucleus.

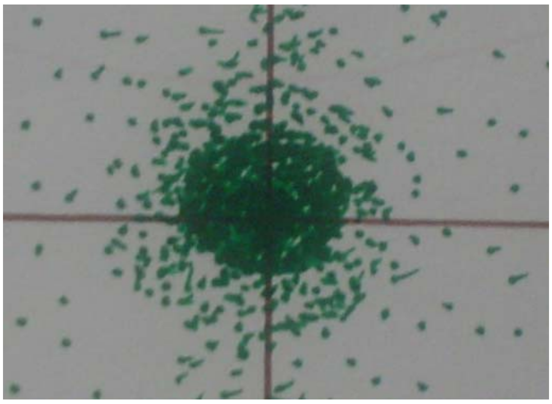


**Figure 4.19** Quantum mechanical model of atom

Moreover, students were able to draw figure of the electron clouds (orbitals), even the complex electrons cloud of *d* and *f* orbitals.

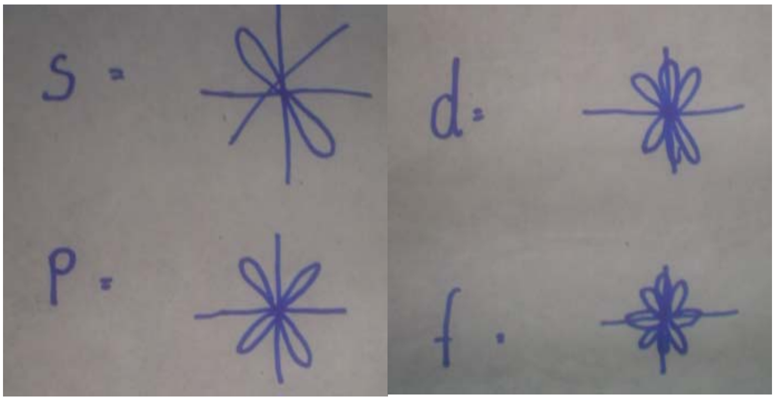



**Figure 4.20** Atomic orbitals

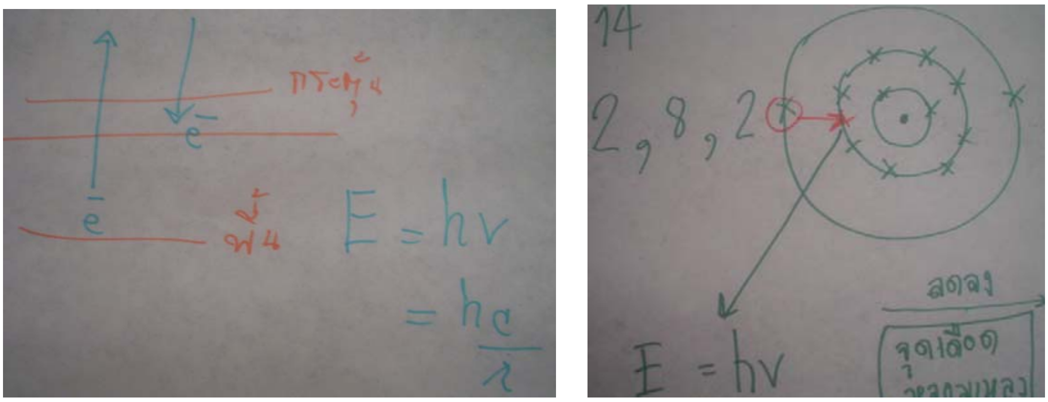
The atomic model students frequently used o express ideas and explained properties of atom, again Bohr's atomic model was popular among school B students. The reason for using the Bohr's model was not different, easier to draw and comfortable to use in explanations.

### 4.1.2 Experiments Study of Sub Atomic Particles

School B student showed low visuospatial ability in this topic. They usually used static verbal statement to decode discovery of scientists, and also figure was barely used here. Most of the students tended to not explain how each sub atomic particle was discover, what happened during the experiments. They just stated scientists' name and their work e.g. "Rutherford discovered atomic nucleus". However, students performed properly in explanation during the interview. Yet, only the experiments which contained video animations such as Rutherford 's gold foil experiment.

### 4.1.3 Atomic Spectra

There were numerous students held high visuospatial of atomic spectra. Students were able to draw phenomena which occurred while atom emits lights (atomic spectra), The representative atomic spectra was demonstrated used Bohr's atomic model in two different ways, presented whole atom or only the energy levels.




**a.** **b.**

**Figure 4.21** The explanation for spectrum

### 4.1.4 Electron Configuration

There were two preferable electron configuration styles found in students' works, Bohr's diagram and Aufbau's diagram. Students were able to use the periodic table (noble gases) for electron configuration, just they scarcely mentioned in their work, The high visuospatial ability also found here, students represented electron configuration exploit in term of figure both Bohr's diagram and Aufbau's diagram. Using Bohr's diagram, students expressed the number pattern 2 8

18 32 rather the formula, $2n^2$ even though they were able to use it. Students also held display of Aufbau's diagram in their mind. Students expressed their mental image of the order of electron in term of Aufbau's diagram. Interestingly, along with the figure of orbitals order in Aufbau's diagram, students were likely to use □ represented sub orbitals (see Figure 4.22).

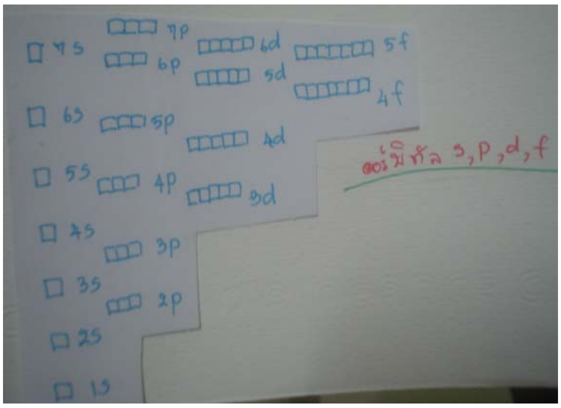



**Figure 4.22** Aufbau's diagram

Although school B students were able to draw figure of every atomic orbital, able to use Aufbau's diagram even well done in the activity "VAST-models and Atomic structure" which using VAST-models constructed structure of atom, ions, and isotopes of the elements as well as determined properties of them still found students held low visuospatial ability which could not image the three dimensional atomic structure, how orbitals arrange in quantum mechanical model of atom.

VAST-models intended to facilitate student's visualization on the unseen atomic structure. However there were students mentioned that VAST-models limited their imagination of atomic structure.

> "It (VAST-models) had been good for who lack imagination. To me, I rather put together the information and imagine myself what is it (atomic structure) look like".

Anyways, the students who mention they were high imagination not express better visuospatial ability than the others students.

## 4.2 Student Visuospatial Abilities on the Periodic Table

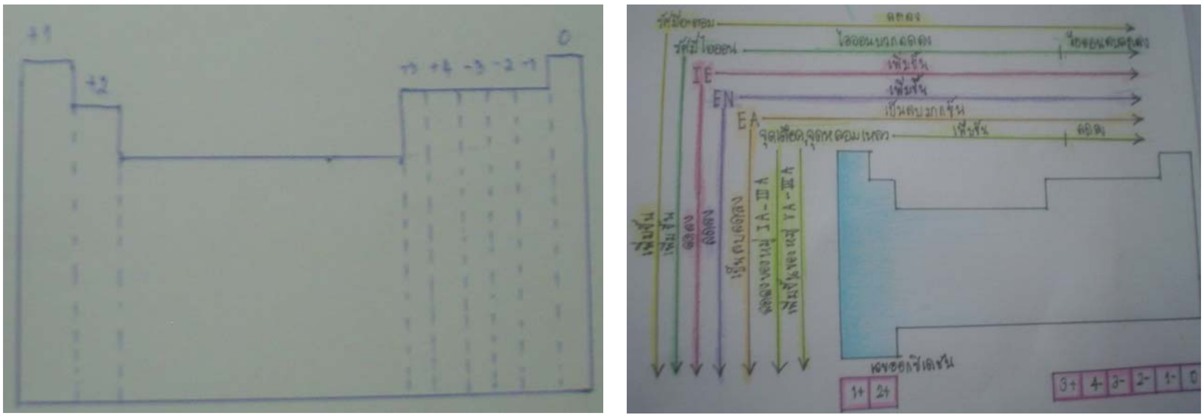
### 4.2.1 Position of Elements in the Periodic Table

School B students mentioned to the discovery of knowledge about the periodic table used a static verbal statement. Again, compared to the discovery of topic sub atomic particle which included video animations, non video animations aid the topic of discovery of the periodic table provided numerous students low visuospatial ability. In the student chemistry textbook the details of the discovery of sub atomic particles and the discovery of the periodic table was equal. This was significant that the video animations enhance students' visuospatial ability.

The same as occurred with the previous topics, school B students rather expressed not much picture. Very few figures of the periodic table were stated in their work. Contrast, students were able to indicate position of metals, nonmetal, and metalloids in the periodic table. This could infer that students held high visuospatial ability about the position of the elements in the periodic table. Students' may not see the important of this topic so omitted to mention about it.

### 4.2.2 The Chemical Periodicity of the Elements

There was obviously that student visuospatial ability influenced students understanding of chemical periodicity of the elements which referred to trends of elements' properties in the periodic table. The finding revealed that school B students done satisfied with this topic. This congruent with data from students' works that Most of the students were able expressed trends of properties in the drawing, even oxidation numbers were indicate belong to the groups of the periodic table (see Figure 4.23).




a. b.

**Figure 4.23** Trends of elements' properties

Regrettably, school B students not mentioned the phenomena occurred to an atom during the process; ionization, electronegativity, or electron affinity in their works. Even though they were able defined definitions of those phenomena, however this rote remembering was not related any to the visuospatial ability.

**5. Student Perspective of the Atomic Structure and the Periodic Table Instructional Units Using Visuospatial Models**

The questionnaire recovery percentage of school B was 86% (37/43). There were 68% of female and 28% of male. In the semester 2/2548, the semester before conducting the research, nearly half of students (43%) got grade 4.00 in chemistry, 24% got grade 3.50, 19% got grade 3.00, and 8% got grade 2.50. None of them received a chemistry grade in semester 2/2548 lower than grade 2.50.

**5.1 Students' Perspective of Understanding Level of Concepts in Atomic Structure and the Periodic Table**

The participant students' perceptions of learning concepts in atomic structure and the periodic table regarding their perspective of understanding level respect to each concept is showed in Table 4.11. Most of participant students from school B indicated that they felt knowledgeable in almost all concepts. The highest percentage that students mentioned to very knowledgeable was electron configuration concepts, 57%. The category little knowledgeable was mentioned to the concepts of chemical periodicity trends of elements; trend of eletronegativity (32%), trend of electron affinity (28%), and trend of melting point and boiling point (30%). Another concept which also fallen into the category little knowledgeable was quantum numbers and orbitals (30%). The concepts which students mentioned that they confused were atomic mass and calculation (5%), and atomic spectrum and energy calculation (5%).

The results revealed that the concepts which the participant students from school B felt not knowledgeable and confused with concepts relevance to the chemical periodicity trends of the elements; electronegativity, electron affinity, melting point and boiling point, ionization energy, oxidation numbers, atomic size, and oxidation numbers respectively. As well as concepts relevance to calculation e.g. atomic mass, atomic spectrum and energy, and quantum numbers was also mentioned at low percentage in category very knowledgeable.

**Table 4.11** School B students' perspective of understanding level of concepts in atomic structure and the periodic table.

| Topics | Concepts | Level of Understanding (% frequency) | | | |
|---|---|---|---|---|---|
| | | Very Knowledgeable | Knowledgeable | Little Knowledge | Confused |
| Atomic Structure | History of atomic structure study | 16 | 78 | 5 | 0 |
| | Properties of sub atomic particles | 19 | 73 | 5 | 3 |
| | Nuclear symbol, atomic number, and mass number | 41 | 54 | 5 | 0 |
| | Isotope | 19 | 62 | 11 | 5 |
| | Atomic mass and calculation | 22 | 68 | 11 | 0 |
| | Atomic spectrum and energy calculation | 8 | 62 | 24 | 5 |
| | Quantum numbers and orbitals | 32 | 35 | 30 | 3 |
| | Electron configurations | 57 | 38 | 5 | 0 |
| The Periodic table | The development of the periodic table | 24 | 73 | 2 | 0 |
| | The arrangement of element into the periodic table | 30 | 60 | 11 | 0 |
| | Trend of atomic size in the periodic table | 38 | 46 | 14 | 3 |
| | Trend of ionization energy in the periodic table | 30 | 46 | 22 | 3 |
| | Trend of electronegativity in the periodic table | 27 | 38 | 32 | 3 |
| | Trend of electron affinity in the periodic table | 19 | 49 | 30 | 3 |
| | Trend of melting and boiling point in the periodic table | 16 | 51 | 30 | 3 |
| | Trend of oxidation numbers in the periodic table | 30 | 60 | 11 | 0 |

Used Pearson product moment correlation coefficient at the level of significant .05 to find correlation between gender of participant students and their perspective of understanding level of concepts in atomic structure and the periodic table, and chemistry grade of participant students in the previous semester (2/2548) and their perspective of understanding level of concepts in atomic structure and the periodic table. Table 4.12 provides the results form this analysis.

**Table 4.12** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of understanding level of concepts in atomic structure and the periodic table of school B students.

| **Topics** | **Concepts** | **r** | |
|---|---|---|---|
| | | **Gender** | **Chemistry Grade** |
| Atomic Structure | History of atomic structure study | 0.03 | 0.47* |
| | Properties of sub atomic particles | 0.05 | 0.43* |
| | Nuclear symbol, atomic number, and mass number | 0.25 | 0.55* |
| | Isotope | 0.10 | 0.26 |
| | Atomic mass and calculation | 0.07 | 0.45* |
| | Atomic spectrum, and energy calculation | -0.04 | 0.25 |
| | Quantum numbers and orbitals | 0.13 | -0.07 |
| | Electron configurations | 0.07 | 0.29 |
| The Periodic table | The development of the periodic table | 0.15 | 0.12 |
| | The arrangement of element into the periodic table | -0.03 | 0.33 |
| | Trend of atomic size in the periodic table | -0.22 | 0.08 |
| | Trend of ionization energy in the periodic table | -0.14 | 0.24 |
| | Trend of electronegativity in the periodic table | -0.12 | 0.13 |
| | Trend of electron affinity in the periodic table | -0.25 | 0.14 |
| | Trend of melting and boiling point in the periodic table | -0.22 | -0.15 |
| | Trend of oxidation numbers in the periodic table | 0.12 | 0.33 |

$p < .05$

The data from the Pearson product moment correlation coefficient result showed that gender of participant students form school B did not relate to their perspective of understanding level of concepts in atomic structure and the periodic table. On the other hand, there were obviously significant relationship between their chemistry grade and their perspective of understanding level of history of atomic structure study, nuclear symbol, and atomic mass and calculation concept.

### 5.2 Students' Perspective of Using Video Clips in Learning Atomic Structure and the Periodic Table

School B students' perceptions regarded to perspective of using video clips in learning concepts of atomic structure and the periodic table are summarized in Table 4.13.

**Table 4.13** School B students' perspective of using video clips in learning atomic structure and the periodic table.

| Video Clips | Using Video clips (% frequency) | | |
|---|---|---|---|
| | Very Helpful | Helpful | Not Helpful |
| Thomson's experiment | 43 | 57 | 0 |
| Milligan's experiment | 30 | 65 | 5 |
| Rutherford's experiment | 57 | 43 | 0 |
| The electron cloud model VS Bohr's model of atomic structure | 32 | 60 | 8 |
| Excited electron and electronic spectrum | 11 | 73 | 16 |
| Ionization of elements | 16 | 70 | 14 |
| Electron affinity of negative electrons | 14 | 62 | 24 |

The participant students from school B indicated that all of video clips were helpful for their learning concepts in atomic structure and the periodic table. The video clip of Rutherford's experiment was mentioned very helpful at highest percentage, 57%, following by video clip of Thomson's experiment (43%). The video clips which were mentioned as not helpful were the video clips of electron affinity of negative electrons (24%) and the video clips of excited electron and electronic spectrum (16%), respectively.

The participant students gave reasons that video clips were helpful for learning concepts in atomic structure and the periodic table because they made the concepts understandable more than reading or verbal description (43%), helped to visualize abstract concepts (16%), and made lessons fun and interesting (3%). The weaknesses of the video clips were indicated that the vocabulary used in the video clips was hard to understand (3%) and the video clips were too short (3%). The participant students advised that the video clips would be more helpful if they were in movie or cartoon form (3%).

The Pearson product moment correlation coefficient at the level of significant .05 between gender of participant students and their chemistry grade in semester 2/2548 were tested with students' perspective of using video clips for learning concepts in atomic structure and the periodic table (see Table 4.14). Data indicated that there was no correlation between gender of participant and their perspective of using video clips for learning concepts in atomic structure and the periodic table. This was identical to the relationship between chemistry grade in semester 2/2548 of the participant students and their perspective of using video clips for learning concepts in atomic structure and the periodic table, which are also not related to each other.

**Table 4.14** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of using video clips for learning concepts in atomic structure and the periodic table of school B students.

| **Video Clips** | **r** | |
|---|---|---|
| | **Gender** | **Chemistry Grade** |
| Thomson's experiment | -0.05 | 0.22 |
| Milligan's experiment | 0.05 | 0.23 |
| Rutherford's experiment | -0.23 | -0.04 |
| The electron cloud model VS Bohr's model of atomic structure | 0.01 | 0.26 |
| Excited electron and electronic spectrum | -0.28 | 0.23 |
| Ionization of elements | -0.08 | 0.25 |
| Electron affinity of negative electrons | -0.09 | 0.20 |

$p < .05$

### 5.3 Students' Perspective of Using VAST-models in Learning Atomic Structure and the Periodic Table

Students' perspective of using VAST-models respect for learning concepts of atomic structure and the periodic table is introduced in Table 4. 15 The VAST-models were indicated helpful for learning all concepts in atomic structure and the periodic table at frequency more than 50%. They were mentioned very helpful in learning concepts of atomic orbital's shapes and the arrangements of orbitals in atom (43%) and electron configurations (41%). Interestingly, students also mentioned that the using VAST-models was not helpful for learning concepts which they previously mentioned very helpful, 19% for atomic orbital's shapes and the arrangement of orbitals in atom and 16% for electron configurations, respectively. Fortunately, the percentage frequency of the category very helpful was greater than the category not helpful.

**Table 4.15** School B students' perspective of using VAST-models in learning atomic structure and the periodic table.

| Concepts | Using VAST-models (% frequency) | | |
|---|---|---|---|
| | **Very Helpful** | **Helpful** | **Not Helpful** |
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | 43 | 53 | 19 |
| Electron configurations | 41 | 541 | 3 |
| Isotopes | 16 | 65 | 16 |
| Arrangement elements into the periodic table | 27 | 62 | 8 |

The participant students from school B indicated the benefits of using VAST-models for learning concepts in atomic structure and the periodic table. They concluded that VAST-models made concepts understandable more than reading and verbal description (35%), helped to visualize abstract concepts (14%), helped to remember contents (5%), were useful for self study (5%), made lessons fun and interesting (3%), helped to make understanding atomic structure and atomic orbitals' arrangement (3%), and helped to make understanding of electron configurations (3%). However, some of students mentioned weaknesses of using VAST-models. Students indicated that VAST-models confused them (8%), were hard to understand (5%), and reduced imagination (3%). Additionally, 3% of students suggested that the amount of VAST-models hands-on set should be in balance with number of students (we have only 15 sets, which means students had to share 2-3 persons per set).

The data of Pearson product moment correlation coefficient at the level of significant .05 for gender of participant students and their perspective of using VAST-models for learning concepts in atomic structure and the periodic table (see Table 4.16) showed the same information as the Pearson product moment correlation coefficient result for chemistry grade in semester 2/2548 of the participant students and their perspective of using VAST-models for learning concepts in atomic structure and the periodic table. There was no relationship between those variables and students' conceptual learning using VAST-models.

**Table 4.16** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of using VAST-models for learning concepts in atomic structure and the periodic table of school B students.

| **Concepts** | **r** | |
|---|---|---|
| | **Gender** | **Chemistry Grade** |
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | -0.10 | -0.08 |
| Electron configurations | 0.04 | -0.0.8 |
| Isotopes | 0.03 | 0.15 |
| Arrangement elements into the periodic table | -0.03 | 0.13 |

$p < .05$

## School C

### 1. The Classroom Practice: Teacher Teaching and Students Learning by the Instructional Units Using Visuospatial Models

#### 1.1 Classroom setting

The classroom used for the case study class consisted of two rows table are shown in figure 4.24. The class was clouded, there were 6-8 students sat in each table.

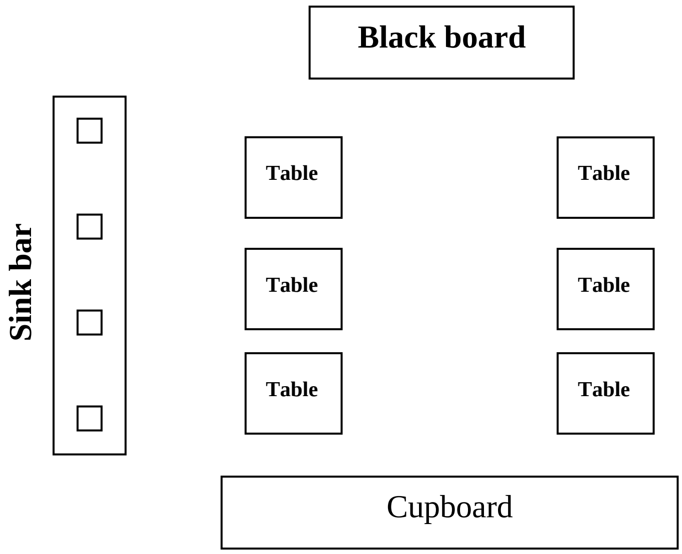



**Figure 4.24** A classroom setting of school C

The groups of students were random assigned by the teacher at the beginning of classroom learning. Students seated in the same group as a whole semester long.

### 1.2 The Classroom Practice: Teacher Teaching and Student Learning by the Instructional Units Using Visuospatial Models

#### 1.2.1 Visuospatial Models and the Discussions

Wanarat, again, started the units by exploring students' existing knowledge using questions. Since she was assigned students' groups her self, Wanarat preferred asking questions to each group of student. Thus the answers usually come from only one person in the group rather than on agreement of the group. The teacher saw this problem then she changed asking question to an individual student instead. The subsequence classroom learning was doing classroom activities; worksheets or experiments. A classroom discussions were followed the classroom activities and the teacher demonstration of the visuospatial model; VAST-models and video clips.

**Figure 4.25** A classroom discussion

The discussions about the visuospatial models were more often with video clips. There were two kinds of content in the video clips about experimental study of scientists and phenomena occurred in atom. Students were requested to predict, interpret give a causal explanation the video clips they have been observed. The teacher encouraged students' thinking by raising questions.

Wanarat: How can atomic model that Rutherford proposed explain experimental result? (pointed to student one in group A and called student's name)

Student 1: Most of $\alpha$-particles passed straight trough the gold foil, this means they found anything, so concluded most of atomic area is empty space.

Wanarat: How about the $\alpha$-particles which go straight back, student 2?

Student 2: They must found something which has positively charge like them.

The discussion using VAST-models were, again, the same pattern with the other two schools, with the concepts of orbitals arrangement and electron configuration. The three-dimensional figure of atom was revealed by the VAST-models. Students were able to see through the penetrate VAST-models and observed the orbitals and their electrons in the simulation atomic structure. Moreover, the teacher also demonstrates how to put neutrons and protons into the atomic nucleus. School C students had no question during the VAST-models demonstration. However, the discussion occurred when the students started the hands-on working themselves.

Wanarat: Why do you put protons and neutrons in the separate part of the atomic nucleus? Any theory behind that?

Wanarat raised this question to the class.

Wanarat: How do you do with protons and neutrons in the nucleus? Show me you nucleus?

Each groups showed their atomic nucleus and Wanarat found most of the groups did the same thing, separated protons and neutrons.

Wanarat: Can you explain, why do you think protons and neutrons are living separately in the nucleus?

Students were together immediately responded.

Students: No, we do not mean that. There was easier to put them that way. We know that protons and neutrons united in the nucleus.

The situation produced Wanarat a chance to explain about models' representation.

Wanarat: Your models have to provide information about the real things as much as possible.

The discussion not only provides students conceptual understandings but also concerned them the nature and limitation of models which play important role in science education this day.

#### 4.2.2 Visuospatial Models and the Experiments

There were again the same pattern of using visuospatial models, used with the experiment "Flame Test" and the activity "VAST-models and Structure of the Elements". In the Flame Test experiment, the video clip "State of Electron According to the Bohr's Atomic Model" was used to simulate phenomena of exciting electron and flame color. The teacher chose to demonstrate the video clip after the experiment conduction for students' making transition between two levels of representation, macroscopy level of flame color and microscopy level of an exciting electron.

The VAST-models were used as an inquiry tool for study atomic structure of the element. The models of elements were constructed using VAST-models by the teacher and the researcher. The groups of students were asked to interpret the models about their properties e.g. electron configuration number of each subatomic particle, isotope, name, and symbol of the elements. At the end, the class was shared the answer and corrected again by the teacher.

**2. Student Understanding of Concepts in Atomic Structure**

All participant students of school C (43 students) were explored their understanding of concepts in atomic structure. Table 4.17 demonstrates the numbers and percentages of school C students' given answer. The results of students' understandings are discussed following the main concepts in atomic structure and the periodic table.

**Table 4.17** Numbers and percentages of given answer for the questions about atomic structure of school C students.

| Concepts | Question No. | SU | | PU | | AU | | NU | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** |
| Model | 1 | 3 | 7 | 0 | 0 | 38 | 88 | 2 | 5 |
| Properties of sub atomic particles | 2 | 25 | 58 | 15 | 35 | 1 | 2 | 2 | 5 |
| | 3 | 25 | 58 | 7 | 16 | 9 | 21 | 2 | 5 |
| | 4 | 5 | 12 | 13 | 30 | 2 | 5 | 23 | 53 |
| Atomic model | 5 | 4 | 9 | 0 | 0 | 16 | 37 | 23 | 53 |
| | 6 | 18 | 42 | 20 | 47 | 5 | 12 | 0 | 0 |
| Atomic number, atomic mass, and nuclear symbol | 7 | 11 | 26 | 28 | 65 | 3 | 7 | 1 | 2 |
| | 8 | 40 | 93 | 2 | 5 | 0 | 0 | 1 | 2 |
| | 9 | 35 | 81 | 0 | 0 | 4 | 9 | 4 | 9 |
| | 11 | 27 | 63 | 0 | 0 | 9 | 21 | 7 | 16 |
| Isotope and atomic mass | 10 | 11 | 26 | 7 | 16 | 11 | 26 | 14 | 33 |
| | 12 | 10 | 23 | 0 | 0 | 14 | 33 | 19 | 44 |
| | 13 | 20 | 47 | 17 | 40 | 0 | 0 | 6 | 14 |
| Wave properties of atom and atomic spectra | 14 | 38 | 88 | 4 | 9 | 0 | 0 | 1 | 2 |
| | 15 | 31 | 72 | 8 | 19 | 0 | 0 | 4 | 9 |
| Atomic orbitals and electron configurations | 16 | 35 | 81 | 1 | 2 | 2 | 5 | 5 | 12 |
| | 17 | 25 | 58 | 7 | 16 | 9 | 21 | 2 | 5 |
| | 18 | 28 | 65 | 2 | 5 | 10 | 23 | 3 | 7 |
| | 19 | 14 | 33 | 20 | 47 | 1 | 2 | 8 | 19 |

SU = sound understanding, PU = partial understanding, AU = specific alternative understanding, NU = no understanding.

### 2.1 Model

Students' concept of model was explored. Most of the students (38 students, 88%) held alternative understanding; nineteen students (44%) stated that models need experimental result supported, fourteen students (33%) stated that verbal statement is not a model, and five students (12%) stated that models are only in a concrete form. Only 3 students (7%) held a sound understanding for the concept, stated that the verbal statement of Democritus's atomic theory is a model.

### 2.2 Properties of Sub atomic Particle

Students were asked to stipulate the properties of sub atomic particles (proton, electron, and neutron) along with the experimental study of scientists. Pertaining to concept of proton properties, Most of the students (25 students, 58%) held sound understanding that proton has positively charge and moves toward the cathode which has negatively charge. Fifteen students (35%) held partial understanding, stated correctly that proton has positively charge, but remained with problems of understanding and confusion of electrodes' charges (cathode and anode) (4 students, 9%), electric attraction/repulsion of proton and the electrodes (7 students, 16%) and both (4 students, 9%). There was only one student (2%) held alternative understanding: negative protons move toward negative cathode. This statement revealed that the student did not comprehend about charges of sub atomic particles and electrodes as well as the common rule of electric attraction/repulsion.

In the concept of properties of electron (cathode rays) found most of the students (25 students, 58%) held sound understanding for the concept: Thomson made a conclusion that cathode rays have negatively charge because they were attracted by anode which has positively charge. Seven students (16%) held partial understanding, stated that cathode rays hold negatively charge because they were deflected by electric field and magnetic field. However, this could not be a conclusion because proton also deflected by electric field and magnetic field. Nine students (21%) held alternative understanding for the concept. Eight students (18 %) held alternative understanding about charge of cathode rays stated; cathode rays have positively charge (6 students) and cathode rays are neutral (2students). Another alternative understanding found was again the rule of electric attraction/repulsion, stated that the negative cathode rays were attracted by negative cathode (1 student).

Considering the concept of properties of nucleus, students were asked to predict result of shooting $\alpha$-particles into atomic nucleus. Five students (12%) held sound understanding: most α-particles will return from the gold foil in the same direction from which it had come because both nucleus and $\alpha$-particles have positively charge. Thirteen students (30%) held partial understanding stated that α-particle will return from the gold foil in the same direction from which it had come because of the weighty nucleus. The alternative understanding found was $\alpha$-particles will pass trough the nucleus with no deflection because the nucleus has no charge (2 students, 5%).

### 2.3 Atomic Model

To explore students' conception about atomic structure, students were asked to predict the result of Rutherford's gold foil experiment. Four students (9%) held sound understanding that most of α-particles passed through the foil with little or no deflection because most of atomic area is empty space. Sixteen students (33%) held alternative understanding. The alternative understanding was students stated that most of α-particles passed through the foil were deflected at very small angles because atom had negatively charged electrons stuck into a lump of positively charged proton (10 students, 23%). This could be interpreted that they held the plum pudding atomic model of Thomson. Another alternative understanding found was student stated that most of $\alpha$-particles were deflected at large angles because they hit the positively charge particles in the nucleus (6 student, 14%). This could be referred that the student focused only on the atomic nucleus not a whole atom

In addition, students' mental model of an atom was explored. Most of the students (18 students, 42%) held mental model of atom as quantum mechanical model of an atom (reason most/scientific model) which referred to the probability of finding an electron within a certain volume of space surrounding the nucleus. The second most of the students (16 students, 37%) held Bohr's atomic model. They mentioned that electrons traveled in a particular path as fixed energy level. The least stated was Thomson's atomic model: electrons stuck into a lump of protons, dispersed through an atom (4 students, 9%).

### 2.4 Atomic Number, Mass Number and Nuclear Symbol

The definition of atomic number and mass number were asked. About a quarter of students (11 students, 26%) held sound understanding that atomic number is the number of proton in atom, if an atom lost or gained proton the element will be changed. Twenty eight students (65%) held partial understanding that atomic number is the number of electron. This answer correct only with atoms, which has equal number of protons and electrons, not included ions. Three students (7%) held alternative understanding that atomic number is the number of neutrons in nucleus. And also Most of the students (40 students, 93%) held sound understanding of mass number. They stated that mass number is the sum number of protons and neutrons. The given reason was mass of electron is very less compared to mass of protons and neutrons. However, two students (5%) held partial understanding, stated that mass number is the sum number of protons and neutrons, however, gave a reason that electrons have no mass.

About the nuclear symbol, students were asked to indicate nuclear symbol of the element which has 18 electrons. Most of the students (35 students, 81%) held sound understanding, answered nuclear symbol of the element is ${}^{40}_{18}Ar$ . They explain that the element which has electron 18 particles, the atomic number will be 18 which is Argon. In addition, Argon has 22 neutrons so has atomic mass 40. The nuclear symbol for the element, atomic number is wrote as a subscript in the lower left corner and the mass number as a superscript in the upper left corner. Four students

(9%) held alternative understanding that could not determine atom of element by using number of proton.

Students were also asked to interpret nuclear symbol of $S^{2-}$. Most of the students (27 students, 63%) held sound understanding. They stated that $S^{2-}$ has 16 protons and cited that proton numbers of element never change. The alternative understanding found was $S^{2-}$ had 18 protons; because of the two added electrons (8 students, 19%), and proton number and electron number are always equal (1 student, 2%). This could be inferred that to these students number of protons and number of electron always equal even in ions.

### 2.5 Isotope and Atomic Mass

To find out students' understanding of isotope, students were asked to determine whether $_6X$ and $^{12}C$ are the same element. About a quarter of the students (11 students, 26%) held sound understanding that both elements were the same element, Carbon. Seven students (16%) held partial understanding, stated correctly that isotopes are the same element which consist of different masses. However, they mentioned that X may be not the Carbon. This could be interpreted that students did not really understand what isotopes are, especially the term "same element" which refer to the same atomic number. Eleven students (26%) held alternative understandings for the concept; $_6X$ and $^{12}C$ are not the same element because the element *X* (10 students, 23%) and mass of the element *X* (1 student, 2%) might be vary. This showed again the alternative understanding about relationship between atomic number and isotopes.

For the concept of atomic mass, students were asked to predict amount of two isotopes in nature. Ten students (23%) held sound understanding that an isotope which had mass number closer to atomic mass of the element found more in the nature because atomic mass is a weight average of the element, calculate from measured isotopic abundances. Fourteen students (33%) held alternative understandings; eleven students (26%) stated that they do not have enough information for the interpretation, and three students (7%) stated that the isotope which had more mass number is easier to find in the nature because it is bigger.

Further more, students were asked to calculate atomic mass of isotope. Most of the students (20 students, 47%) held sound understanding for the concept; that atomic mass was a weight average of isotopic abundances. Seventeen students (40%) held partial understandings; fourteen students (33%) used the formula: atomic mass = atomic number of isotope x abundant percentage of the isotope +…, but did not use a specific unit (amu.), and three students (7%) answer only the formula but did not show the solution.

### 2.6 Wave Properties of Atom and Atomic Spectra

Students were asked to calculate wavelength of yellow light. Most of the students (38 students, 88%) held sound understanding for the concept, used the correct formula to solve the problem and successful in calculation. Four students (9%) held partial understandings; one student (2%) mentioned correctly about the formula: $\lambda = \frac{c}{\upsilon}$, where $\lambda$ was wavelength of the yellow light, $c$ was the speed of light, and $\upsilon$ was frequency of the yellow light but did not show the solution work, and three students (7%) demonstrated the calculation without indicated the formula.

In addition, students were asked to calculate quantum energy. Most of the students (31 students, 72%) held sound understanding for the concept. Students did correctly problem solving, correctly conversed the unit (angstrom to meter), and used correct formula to solve the problem ($E = \frac{hc}{\lambda}$, where $E$ was quantum energy, $c$ was the speed of light, and $\lambda$ was a wavelength). Eight students (19%) held partial understandings for the concept. Six students (14%) stated correctly the formula but did not show problem solving and two students (5%) did not use a specific unit for the wavelength (meter).

### 2.7 Atomic Orbitals and Electron Configuration

Students were asked to indicate an electron arrangement of an element. Most of the students (35 students, 81%) held sound understanding for the concept. Thirty two students (74%) were able to use both Aufbau's diagram and the periodic table (noble gas) for doing electron configuration. Two students (5%) were able to use only the periodic table to indicate an electron configuration of the element, and two students (5%) was able to use only Aufbau order of filling. One student (2%) held partial understanding that stated correctly about energy levels (shells) but had confusion about order of orbitals.

Besides this, students were asked to examine the given electron configuration and reasons for electrons' behavior. Most of the students held sound understanding for the concept. Most of the students (25 students, 58%) stated that electrons were fulfilled the lowest energy level before enter the next energy levels. Twenty eight students (65%) indicated that electrons tried arrange as half-filled or filled set of orbitals for enhancing stability of the element. In addition fourteen (33%) stated that electrons in *3s*-orbitals never jump to *3p*-orbitals although for half-filled or filled set arrangement because of the large energy gap between *ns* and *np* orbitals. The partial understandings found were: students were able to use Aufbau's diagram for electron configuration but confused about a written order of orbitals in electron configuration. They stated that the electron configuration [Ar] $3d^{10}4s^{1}\ 4p^{6}$ and the electron configuration [Ar] $4s^{1}3d^{10}4p^{6}$ are different (7 students, 16%). Moreover, students did not know the main reason for electronic skipping form orbital *ns* to orbital (*n*-1)*d* in transition elements, mentioned to orbitals overlapping but did not address to stability enhancing (2 students, 5%), and did not concern about the half-filled and filled set of orbitals in electron configuration of the transition elements (10 students, 23%). In the other hand, did have a group of students which too focused on the stability enhancing to realize about the gap between *3s*-orbitals and *3p*-orbitals, addressed that electrons in *3s*-orbitals would jumped to *3p*-orbitals for half-filled arrangement of electron configuration (20 students, 47%) which is a alternative understanding. The addition alternative understandings found were: students did incorrect about order of orbitals in electron configuration (1 student, 2%), did not know length of gap between orbitals, indicated electronic skipping between orbitals which not close to each other e.g. *4s*-orbital and *4p*-orbital (2 students form Q17 and 1 student from Q19).

### 3. Student Understanding of Concept in the Periodic Table

All participant students of school C (43 students) were explored their understanding of concepts in the periodic table. Table 4.18 demonstrates numbers and percentages of given answers for the questions about concepts in the periodic table. The results are discussed following the main concepts in the periodic table.

**Table 4.18** Numbers and percentages of given answer for the questions about the periodic table of school C students.

| Concepts | Question No. | SU | | PU | | AU | | NU | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** | ***n*** | ***%*** |
| The periodic table and electron configuration | 20 | 35 | 81 | 0 | 0 | 0 | 0 | 8 | 19 |
| Chemical properties and a physical properties of metals, nonmetals, and metalloids | 21 | 27 | 63 | 3 | 7 | 10 | 23 | 3 | 7 |
| | 22 | 27 | 63 | 3 | 7 | 11 | 26 | 2 | 5 |
| | 23 | 18 | 42 | 21 | 49 | 0 | 0 | 4 | 9 |
| | 24 | 16 | 37 | 4 | 9 | 1 | 2 | 22 | 51 |
| | 25 | 13 | 30 | 0 | 0 | 27 | 63 | 3 | 7 |
| | 26 | 25 | 58 | 0 | 0 | 8 | 18 | 10 | 23 |
| Atomic radii | 27 | 28 | 65 | 0 | 0 | 5 | 12 | 10 | 23 |
| Ionization energy | 28 | 29 | 67 | 0 | 0 | 2 | 5 | 12 | 28 |
| | 29 | 36 | 84 | 0 | 0 | 2 | 5 | 5 | 12 |
| | 31 | 11 | 26 | 23 | 54 | 2 | 5 | 7 | 16 |
| | 32 | 9 | 21 | 24 | 56 | 0 | 0 | 10 | 23 |
| Ionic radii | 30 | 22 | 51 | 10 | 23 | 9 | 21 | 2 | 5 |
| Electronegativity | 33 | 18 | 42 | 0 | 0 | 2 | 5 | 23 | 53 |
| | 34 | 1 | 2 | 27 | 63 | 0 | 0 | 15 | 35 |
| Electron affinity | 35 | 1 | 2 | 0 | 0 | 33 | 77 | 9 | 21 |
| | 36 | 9 | 21 | 0 | 0 | 20 | 70 | 4 | 9 |
| Melting point and boiling point | 37 | 25 | 58 | 7 | 16 | 6 | 14 | 5 | 12 |
| | 38 | 38 | 88 | 1 | 2 | 1 | 2 | 3 | 7 |
| Oxidation number | 39 | 26 | 61 | 0 | 0 | 10 | 23 | 7 | 16 |
| | 40 | 36 | 84 | 0 | 0 | 4 | 9 | 3 | 7 |

SU = sound understanding, PU = partial understanding, AU = alternative understanding, NU = no understanding.

### 3.1 The Periodic Table and Electron Configuration

Students were asked to determine group and period in the periodic table of an element. All of the students who completed the answer (35 students, 81%) held sound understanding for the concept, were able to use electron configuration to specify group and period of the element, and correctly stated that the outer most energy level indicates period, and valence electrons indicates group in the periodic table of the element. However, students used different methods demonstrated electron configuration of the element. Most of the students (17 students, 40%) used Aufbau's diagram, thirteen students (30%) used Bohr's diagram, one student (2%) used noble gas configuration (the periodic table), three students (7%) used both Aufbau's diagram and Bohr's diagram, and one student (2%) used both Aufbau's diagram and the periodic table noble gases configuration.

### 3.2 Chemical Periodicity of Elements

The eight concepts of chemical periodicity of element were required; (1) chemical and physical properties of metals, nonmetals, and metalloids, (2) atomic radii, (3) ionization energy, (4) ionic radii, (5) electronegativity, (6) electron affinity, (7) melting point and boiling point, and (8) oxidation number.

#### 3.2.1 Chemical and Physical Properties of Metals, Nonmetals, and Metalloids

Students were asked to predict the stability of atoms and ion, they were asked to compare stability of Zinc and Rhodium, further more they were asked to compare stability of Sulfur atom and Sulfur ion. Most of the students held sound understanding; twenty seven students (63%) stated that Zinc is more stable than Rhodium and twenty seven students (63%) stated that Sulfur ion is more stable than

Sulfur atom because they hold a filled arrangement of the electron configuration. The partial understandings found were; all transition elements hold the same properties so the stability of Zinc and Rhodium (3 students, 7%), and Sulfur ion is more stable than Sulfur atom because percent abundance of Sulfur ion in natural is more than Sulfur atom (3 students, 7%). There were also alternative understanding emerged. Ten students (23%) held alternative conception about size of atom and stability: seven students (16%) stated that the bigger atom (Rhodium) is more stable, and three students (7%) stated that smaller atom (Zinc) is more stable. Eleven students (26%) held alternative understanding about electron repulsion, stated that the two extra electrons of Sulfur ion cause Sulfur ion less stable compared to Sulfur atom. Two students (5%) held alternative conception that the same element has same properties either atom or ion (Sulfur atom and Sulfur ion hold the same stability).

Students were asked about malleable ability (can be hammered into sheets) and ductile ability (can be drawn into wires) of metals. The second Most of the students (18 students, 42%) held sound understanding, stated that metals have malleable ability and ductile ability because the mobile electrons of metallic bonding belong to the metallic whole crystal. Most of the students (21 students, 49%) held partial understanding correctly stated that metals have malleable ability and ductile ability, however there was some mistakes in their explanations. Eight students (19%) stated that only massive metal hold malleable ability and ductile ability and thirteen students (30%) stated that malleable ability and ductile ability depend on size of metal atom. Only electrons of small atom able to mobilize to neighbor atom, on the other hand, electrons of big atom could not.

Students were asked about properties of nonmetal elements. Most of the students (16 students, 37%) held sound understanding, stated that not all of nonmetal elements are gases, the massive nonmetal elements are solids. Four students (9%) held partial understanding stated that nonmetal elements have low melting and boiling points so they were all gases. One student (2%) held alternative understanding: nonmetals are small in size compared to metals and metalloids in the same period of the periodic table so student thought the small atom of nonmetals is light. The light nonmetal atoms affected them floatable as elements in gas state.

Students were asked to examine conductivity of metalloids. Thirteen students (13 students, 30%) held sound understanding that the conductivity of metalloid is getting better after heating because their electrons are moving faster. However, twenty seven students (63%) held alternative understanding. The alternative understanding found were; at higher energy levels electrons of metalloid form metal bonding so they have better conductivity (23 students, 54%), and metalloids had no conductivity because they form covalent bonding (4 students, 9%).

Students were asked to determine reason that causes high stability of noble gases. Most of the students (25 students, 58%) held sound understanding, gave a reason that because of noble gases hold filled arrangement of the electron. The alternative understandings found were as following. One student (2%) stated noble gases stable because they hold the highest effective nuclear charge so smallest in the period. Therefore their electrons face difficulty escape from their atoms. Seven students (16%) stated that this is because of the electric attraction force between protons and electrons in noble gases atoms, their highest number of electron and protons resulted highest attraction force, this causes them tend to not give or share their electrons.

### 3.2.2 Atomic Radii

Students were asked to determine atomic radii from the given electron configuration. Most of the students (28 students, 65%) held sound understanding that atomic radii of the atom which has electron configuration $1s^22s^22p^63s^1$ is not the smallest atom of the period which it occupy. The smallest atom of each period was in group VIIA, not group IA as this atom. Six students (14%) held alternative understanding; two students (5%) stated that the smallest atoms are in group IA, and three students (7%) stated that the orbital 3*s* could filled two electrons so the atom which hold $3s^1$ is smallest in the period.

### 3.2.3 Ionization Energy

Students were asked to predict what will occur to the ionized atoms. Most of the students held sound understanding. Twenty nine students (67%) stated that when sodium atom lose its first electron the remaining ten electrons in the sodium ion ($Na^+$) will experience greater attraction by the nucleus. Students explained the reasons why the ionization energy to remove the second electron from $Na^+$ is greater than the ionization energy of the first electron: Thirteen students (30%) referred to the increasing of electric attraction force affected by nucleus, and twenty three students (54%) elucidated the second electron of Na occupied in the energy level which closer to nucleus than the first electron. Students concluded that the second ionization energy ($IE_2$) is always greater than the first ionization energy ($IE_1$) (9 students, 21%) because of the reasons above. However, the second electron not always occupy in the energy level closer to the nucleus, sometime still in the same energy level. For this statement, there were twenty four students (56%) held partial understanding. The alternative understandings found were; amount of attraction force between an electron and the nucleus depends on the number of protons present in the nucleus and the distance of the electron from the nucleus, does not depend on how many other electrons are present, although electrons do repel each other (2 students, 5%), and $Na^+$ will never lose its electron because it already has the stable filled electron configuration (2 students, 5%).

Furthermore, students were asked to find out trend of ionization energy of Beryllium (Be), Boron (B), Nitrogen (N), and Oxygen (O). About a quarter of students (11 students, 26%) held sound understanding. They ordered the trend of ionization energy as N>O>Be>Be and gave explanation that the first ionization energy ($IE_1$) increase generally increase as moving from left to the right across a period of the periodic table. However, Boron and oxygen rather lose their electron for their stable half-filled and filled electron configuration so $IE_1$ of Beryllium was greater than Boron and Nitrogen was greater than Oxygen. The partial understanding was students gave the right explanation of $IE_1$, however forgot the exception of IE dropping which explained before, answered O>N>B>Be. The right explanations found were; $IE_1$ generally increase as moving from left to the right across a period of the periodic table (9 students, 21%), $IE_1$ depended on size of atoms, the smaller atoms, the higher $IE_1$ (12 students, 28%), and $IE_1$ generally increases moving from IA elements to VIIIA elements along the period (2 students, 5%). Two students (5%) held alternative understanding, $IE_1$ depends on size of elements, and the bigger elements contain greater $IE_1$.

### 3.2.4 Ionic Radii

Students were asked to compare ionic radii of fluoride ion and sodium ion. Most of the students (22 students, 51%) held sound understanding that fluoride ion is bigger than sodium ion because even both ions have the same electron configuration however sodium ion hold higher number of protons. Ten students (23%) held partial understanding, stated correctly that fluoride ion is bigger than sodium ion but gave incorrect explanation that negative ions are always bigger than positive ions. Actually, this statement is correct only with negative ion and positive ion of the same element, could not refer to ions of different elements. Nine students (21%) held alternative understanding; ions which have the same electron configuration, the ion contained lower protons have smaller ionic radii.

### 3.2.5 Electronegativity

Students were asked to order electronegativity of Beryllium (Be), Iron (Fe), germanium (Ge), and Tellurium (Te). Most of the students (18 students, 42%) held sound understanding, indicated Te>Ge>Fe>Be and stated that electronegativities increased from left to right across period and decreased from top to bottom within group of the periodic table. The alternative understandings emerged was the biggest atom has greatest electronegativity (2 students, 5%).

In addition, students were asked what they expected when Hydrogen (H) interact Fluorine (F), forms Hydrogen fluoride molecule (HF). Only one student (2%) held sound understanding that electron tendency was attracted to fluorine because its electronegativity was higher. Most of the students (27 students, 63%) held partial understandings; ten students (23%) stated correctly that electron was attracted to Fluorine, Hydrogen lose an electron forms Hydrogen ion ($H^+$) and Fluorine receives the electron forms Fluoride ion ($F^-$), and seventeen students (40%) stated correctly that HF was a covalent molecule, Hydrogen and Fluorine were sharing their electrons. However, they missed to concern that HF was a polar molecule, so they stated that electron tendency was in the middle.

### 3.2.6 Electron Affinity

Students were asked to decided electron affinity of metals. Only one student (2%) held sound understanding, stated that electron affinities of metals were negative, the addition of an electron to form anion of metals was exothermic. Most of the students (33 students, 77%) held alternative understandings. The alternative understandings found were; to add electron to metal atoms required energy pushing because metals prefer to be cations (14 students, 33%), and it is impossible to form metal anions (9 students, 21%).

However, when students were asked to interpret equation $K (g) + e^- \longrightarrow K^- (g) + 48$ kJ, EA = -48 kJ/mol. Nine students (21%) held sound understanding, indicated that to form potassium anion, potassium atom need to release out the energy, as the basic rule, energy required for bond breaking and released in the bond formation. The alternative understandings found were; negative electron affinity of the equation means the energy required for this equation is less than zero (13 students, 30%), and again the alternative understanding persisted, it is impossible to form potassium anions (17 students, 40%).

### 3.2.7 Melting Point and Boiling Point

Students were asked to predict melting point and boiling point of small size metals. Most of the students (25 students, 58%) held sound understanding that small size metals has high melting point and boiling point because they close packed crystal needs high energy for breaking out. The partial understanding found was metals always hold high melting point and boiling point (7 students, 16%). The alternative understanding found was the small size metals have low melting point and boiling point because they are low in mass so need not much energy for breaking out the crystals (6 students, 14%).

More over, students were asked to consider melting point and boiling point of metals and nonmetals. Most of the students (38 students, 88%) held sound understanding that melting point and boiling point of metals are higher than nonmetals because metals bond of metals was stronger than covalent bond of nonmetal. One student (2%) held partial understanding, stated that melting point and boiling point of metals more than nonmetals because metals are solid whereas nonmetal are gases. The alternative understanding was can not compare melting point and boiling point of elements in different group because they hold different bonding (1 student, 2%).

### 3.2.8 Oxidation Number

Students were asked to indicate oxidation number of sodium (Na) in sodium nitrate ($NaNO_3$). Most of the students (26 students, 61%) held sound understanding, stated that sodium had oxidation number +1 because elements in Group IA have oxidation number +1. The alternative conception found were; oxidation number of element equals oxidation number of the compound which the element composed (6 students, 14%), oxidation number of element atom is zero even when composed compounds (1 student, 2%), and single atom has oxidation number +1(3 students, 7%).

Students further enquired to compare oxidation number of Sulfur (S) in the Sulfuric acid ($H_2SO_4$) and Sulfur dioxide ($SO_2$). Most of the students (36 students, 84%) held sound understanding that oxidation number of S in the compounds is different, +6 in $H_2SO_4$ and +4 in $SO_2$, and explain that oxidation number of element is varied, depends on the compounds its existed. Alternative understandings found were; the same element always hold the same oxidation number (2 students, 5%), and the $H_2SO_4$ and $SO_2$ contain one atom of Sulfur the same so Sulfur in both molecules holds the same oxidation number (2 students, 5%).

## 4. Student Visuospatial Thinking

43 school C students were explored visuospatial thinking along with the instructional units implementation. Their concept mapping classroom activities deal with VAST-models and video animations were require for the visuospatial thinking study. Beside, six students from the class were interviewed at the end of the instructional units implementation. Student visuospatial thinking are following described.

### 4.1 Student Visuospatial Abilities on Atomic Structure

#### 4.1.1 Atomic Models

Students' visuospatial thinking of atomic models were examined between two issues, the scientists atomic models and an atomic which students used in their explaination about concepts in atomic structure. Atomic models which students mentioned in their work were all of atomic models detailed in their chemistry textbook which were atomic structure of Democritus, Dalton, Thomson, Rutherford, Bohr, and the quantum mechanical model of Schrödinger. Most of the students demonstrated these atomic models in term of figures and use visual analogy expressed the target atomic models by using dominant properties of the target atomic models such as 'solar system' referred to Bohr's atomic model, 'electron could' represent quantum mechanical model of Schrödinger. The display of atomic models which students used could infer to their mental image of atomic structure which explicit in their imagination of atomic structure. However, the distance among electron energy levels still a problem for school C students. Students drew figure of Bohr's atomic model used improper distant between each energy level (see Figure 4.26).


**Figure 4.26** Bohr's atomic model of school C student

However, students indicated the proper electron tendency in quantum mechanical model. Students expressed clouded electron tendency at region near atomic nucleus. This was dilemma of students visuospatial ability. This was hard to identify whether students hold high or low visuospatial ability of atomic structure referred to those given answers.

The atomic orbital which school C students preferred to use in the explanation of concepts related atomic structure was again Bohr's atomic models. The given reasons for choosing Bohr's atomic model still its simplicity and useful for atomic's phenomena representation.

> "…Bohr's model is much or easier to use. I know the reasonable atomic modes is electron clad but it's too complicate for me so"

### 4.1.2 Experiments Study of Sub Atomic Particles

The dilemma occurred in the study of this issue. The finding indicated students preferred using figures demonstrate the experiments study of scientists, however their explanations about properties of sub atomic particles were static verbal statements such as "Goldstein used cathode ray tube examine protons and found that protons hold positively charge". From students' words could identified that students may thought that there was no need to explain figures and indicated that these students held high visuospatial ability. To avoid bias, students were asked to explain about those experiments again. The interview results indicate that there were only few experiments students were able to explain and those were demonstrated using video animations in their classroom learning.

The visual analogy found was hand gestures. Students were used hand gestures represented parts of an atom, wave, direction of rays or particles, etc., for example, students moved an arm represent the movement of wave. The verbal analogy not often used, however, the verbal analogy found, for example.

> "…charged oil droplets were attracted to electrode charge likes nail was attracted to magnet".

### 4.1.3 Atomic Spectra

Most of school C students demonstrate figures for explain the occurrence of atomic spectrum and were able to explain about it. The representative figure and explanation were clear. Moreover the formula use for spectrum energy, $E=h\nu$, was also expressed. Most of the figures indicated electron energy levels, which grounded energy level and excited energy level were significantly apart and not next to each other. These appeared that the students held high visuospatial ability of atomic spectra.

### 4.1.4 Electron Configuration

There were only one style of electron configuration found in students' works, the Aufbau's diagram. The Bohr's diagram and the electron configuration used noble gases were not found. The Aufbau's diagram found was not only the orbitals' order but also found students use boxes represented sub atomic orbital (see Figure 4.27).

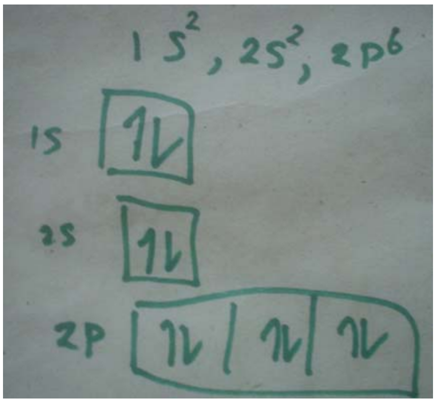



**Figure 4.27** Aufbau's diagram of electron configuration

Some students were indicated also name, shape, and possible sub orbitals of each atomic orbital (see Figure 4.28).

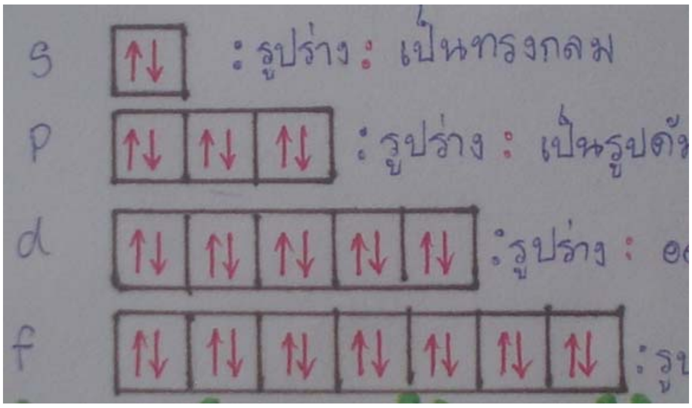



**Figure 4.28** Atomic orbitals and sub atomic orbitals

If combined the finding that previously mention; students were able to use Aufbau's diagram and students were able to draw every atomic orbitals, it seems students could able to indicate how atomic orbitals arrange in the atomic structure. Rather, the study revealed that the ability to image and represent two-dimensional figure of students were not related to ability to image three-dimensional figure. And also, interesting that students were able to use the concrete three-dimensional atomic structure, VAST-models as they did on the activity "VAST-models and atomic structure". (see Figure 4.29). How come that school C students were not able to identify atomic orbitals which contained in each energy level.

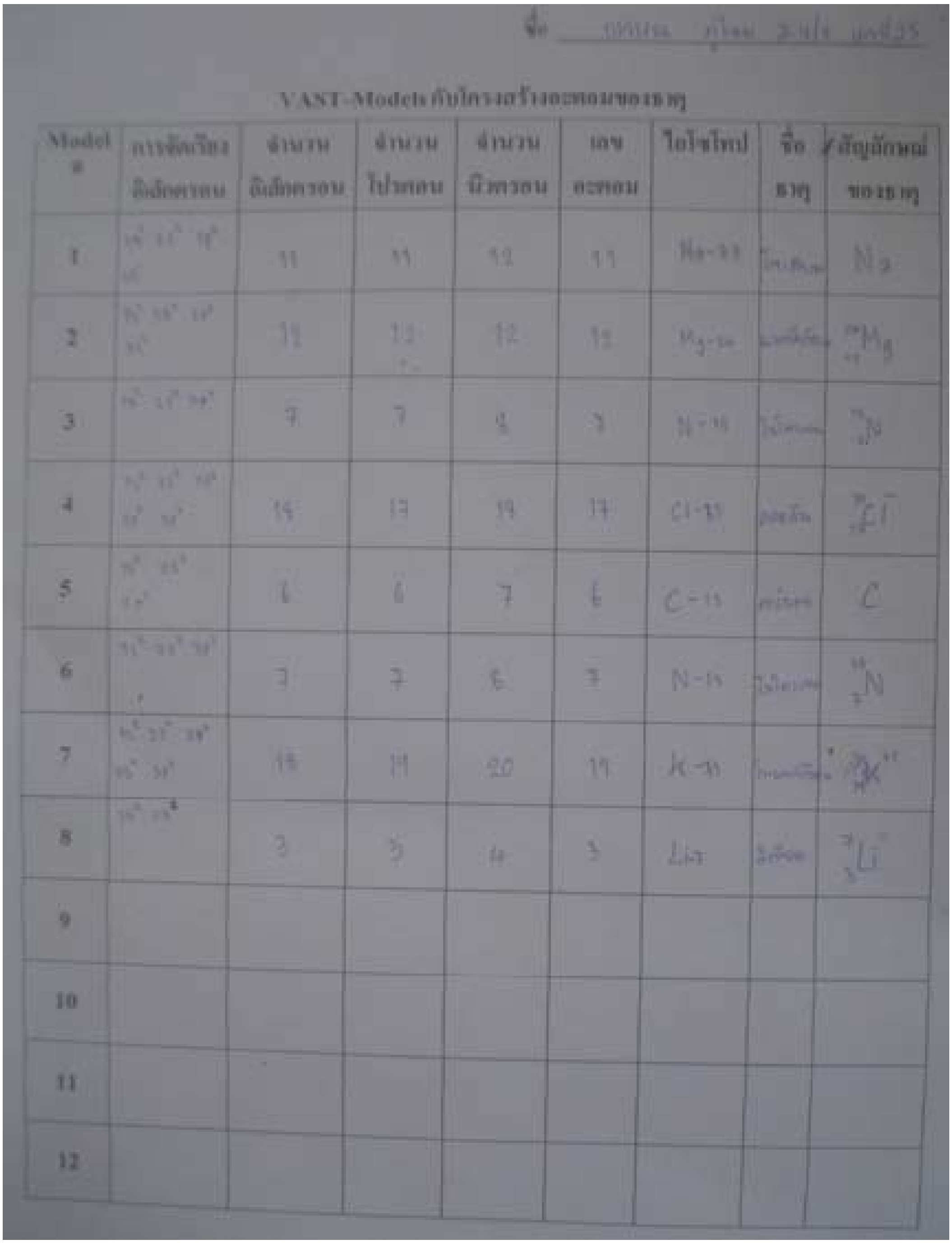
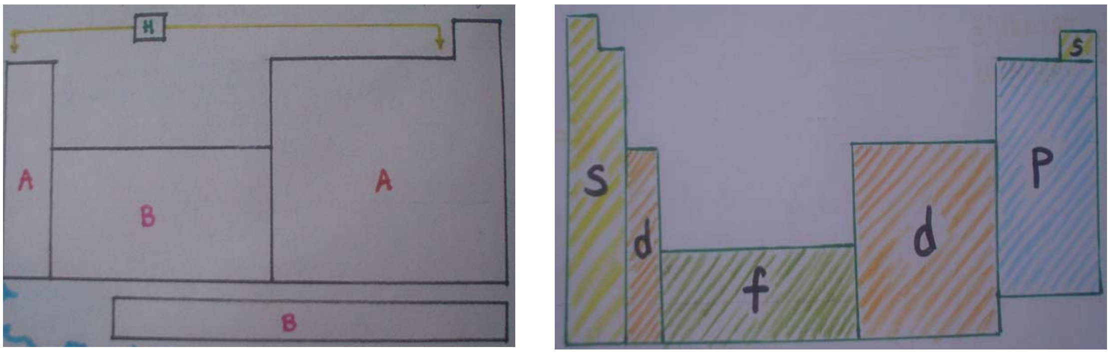


**Figure 4.29** School C students' paper work

## 4.2 Student Visuospatial Abilities on the Periodic Table

### 4.2.1 Position of Elements in the Periodic Table

School C students presented the periodic table using the orbital of valence electrons (*s, p, d, f*), and using principle groups of elements, representative elements (A) and transition elements (B) are shown in figure 4.30.




**a.** **b.**

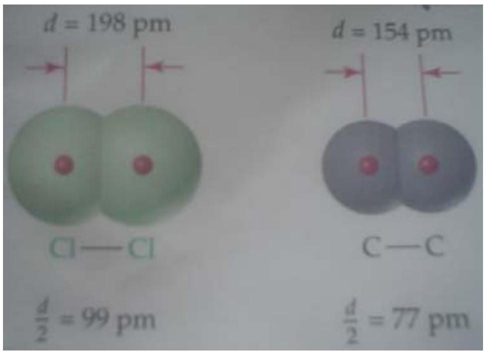
**Figure 4.30** The periodic table of school C students

The history of the periodic table development was barely started by students. Some of the found statements just detailed name of scientists and their discovery, however in static way. The visual analogy also not found here.

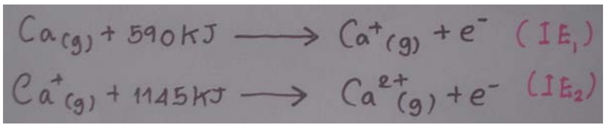
Anyways, the finding from the interview proved that school C students not held low visuospatial ability in all topics of the periodic table. Students were asked to indicate position of metals, nonmetal, and metalloid elements in the periodic table. The result indicated that students were held high spatial ability of this topic. They were able to locate those groups of elements without using the periodic table.

### 4.2.2 Chemical Periodicity of the Elements

About this topic, there were explicit that students held high visuospatial ability. Students were able to explain concepts based on experiments, able to represent concepts in term of display image, able to use chemical equation expressed the concept, and even verbal statements were all in dynamic way (see Figure 4.31).




a.




b.

**Figure 4.31** Visual displays of concepts

Moreover, in the interview found that students who were able to explain the properties' trend of elements, always draw figure of chemical periodicity of elements before give an explanation. This finding could use for proving the relationship between student visuospatial ability and achievement in chemistry.

**5. Student Perspective of the Atomic Structure and the Periodic Table Instructional Units Using Visuospatial Models**

The recovery percentage of questionnaire for school C was 98% (42/43). The participant students were 55% male and 45% female. 74% of them received grade

4.00 in chemistry in semester 2/2548, the semester before conducting the research study. 12% got grade 3.50, 5% got grade 3.00, and none of them got chemistry grade lower than grade 3.00.

### 5.1 Students' Perspective of Understanding Level of Concepts in Atomic Structure and the Periodic Table

The participant students' perspective of understanding level of learning concepts in atomic structure and the periodic table introduced in Table 4.19. The highest percentage of students' mentioned was the category knowledgeable. More than 50% of participant students indicated that they felt knowledgeable with almost all concepts except nuclear symbol, atomic number, and mass number concept (48%) and trend of oxidation numbers in the periodic table (4%). The concept which students mentioned as highest frequency of category very knowledgeable was electron configurations concept, 62%. The concept that mentioned the lowest percentage of category very knowledgeable was trend of electron affinity, 10%. There were four concepts that students stated confused them in the highest percentage.  7% of the students listed these concepts as atomic spectrum and energy calculation concepts, trend of atomic size, trend of electronegativity, and trend of electron affinity in the periodic table.

The data referred that the participant students from school C felt unconfident with the concepts about chemical periodicity trends of elements such as atomic size, electronegativity, and electron affinity. Especially, electron affinity that was indicated at the lowest percentage in category very knowledgeable and highest percentage in category confused. Moreover, students felt that they have not knowledgeable in the concept of atomic spectrum which full of calculation.

**Table 4.19** School C students' perspective of understanding level of concepts in atomic structure and the periodic table.

| Topics | Concepts | Level of Understanding (% frequency) | | | |
|---|---|---|---|---|---|
| | | **Very Knowledgeable** | **Knowledgeable** | **Little Knowledge** | **Confused** |
| Atomic Structure | History of atomic structure study | 31 | 67 | 2 | 0 |
| | Properties of sub atomic particles | 24 | 64 | 12 | 0 |
| | Nuclear symbol, atomic number, and mass number | 50 | 48 | 2 | 0 |
| | Isotope | 29 | 62 | 7 | 2 |
| | Atomic mass and calculation | 33 | 60 | 7 | 0 |
| | Atomic spectrum and energy calculation | 17 | 60 | 17 | 7 |
| | Quantum numbers and orbitals | 21 | 62 | 14 | 2 |
| | Electron configurations | 62 | 36 | 2 | 0 |
| The Periodic table | The development of the periodic table | 24 | 67 | 10 | 0 |
| | The arrangement of element into the periodic table | 31 | 64 | 5 | 0 |
| | Trend of atomic size in the periodic table | 36 | 50 | 7 | 7 |
| | Trend of ionization energy in the periodic table | 36 | 50 | 10 | 5 |
| | Trend of electronegativity in the periodic table | 17 | 62 | 14 | 7 |
| | Trend of electron affinity in the periodic table | 10 | 69 | 14 | 7 |
| | Trend of melting and boiling point in the periodic table | 17 | 57 | 21 | 5 |
| | | 33 | 45 | 17 | 5 |

Examine the relationship of gender and chemistry grade of participant students in the semester 2/2548 with students' perspective of their understanding level of concepts in atomic structure and the periodic table used Pearson product moment correlation coefficient at the level of significant .05 (see Table 4.20). The test result revealed that gender of participant students related to students' perspective of their understanding level of the concept trend of oxidation numbers in the periodic table. And the chemistry grade of student related to students' perspective of their understanding level of the concept atomic mass and calculation.

**Table 4.20** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of understanding level of concepts in atomic structure and the periodic table of school C students.

| Topics | Concepts | r | |
|---|---|---|---|
| | | **Gender** | **Chemistry Grade** |
| Atomic Structure | History of atomic structure study | 0.00 | 0.13 |
| | Properties of sub atomic particles | 0.00 | 0.00 |
| | Nuclear symbol, atomic number, and mass number | -0.05 | 0.08 |
| | Isotope | -0.13 | 0.29 |
| | Atomic mass and calculation | 0.28 | -0.21 |
| | Atomic spectrum, and energy calculation | -0.12 | 0.00 |
| | Quantum numbers and orbitals | 0.13 | 0.21 |
| | Electron configurations | 0.17 | 0.04 |
| The Periodic table | The development of the periodic table | 0.19 | -0.03 |
| | The arrangement of element into the periodic table | 0.07 | 0.08 |
| | Trend of atomic size in the periodic table | 0.21 | -0.09 |
| | Trend of ionization energy in the periodic table | 0.25 | -0.06 |
| | Trend of electronegativity in the periodic table | 0.23 | 0.32 |
| | Trend of electron affinity in the periodic table | 0.21 | 0.22 |
| | Trend of melting and boiling point in the periodic table | 0.28 | 0.20 |
| | Trend of oxidation numbers in the periodic table | 0.23 | -0.17 |

$p < .05$

## 5.2 Students' Perspective of Using Video Clips in Learning Atomic Structure and the Periodic Table

Perceptions of the participant students regarding to their perspective of using video clips in learning concepts of atomic structure and the periodic table are summarized in Table 4.21.

**Table 4.21** School C students' perspective of using video clips in learning atomic structure and the periodic table.

| Video Clips | Using Video clips (% frequency) | | |
|---|---|---|---|
| | **Very Helpful** | **Helpful** | **Not Helpful** |
| Thomson's experiment | 48 | 48 | 5 |
| Milligan's experiment | 38 | 55 | 7 |
| Rutherford's experiment | 60 | 36 | 5 |
| The electron cloud model, and Bohr's model of atomic structure | 41 | 52 | 7 |
| Excited electron and electronic spectrum | 41 | 57 | 2 |
| Ionization of elements | 21 | 69 | 10 |
| Electron affinity of negative electrons | 24 | 60 | 17 |

The data suggests that most of participant students felt the video clips were helpful for their learning concepts in atomic structure and the periodic table at rates above 50% of frequency. They indicated that the video clip of Rutherford's and of Thomson's experiment were very helpful for their learning as 60% and 48%, respectively. The video clips which were highest mentioned as not helpful were video clips of electron affinity of negative electrons (17%) and ionization of elements (10%). Especially, the video clip of electron affinity of negative electrons was mentioned at a low percentage of very helpful category and highest percentage of not helpful category.

The participant students explained more what they liked about using the video clips for learning concepts in atomic structure and the periodic table. They mentioned that the video clips made the concepts understandable more than reading or verbal description (21%), helped to visualize abstract concepts (12%), made lessons fun and interesting (5%), helped to remember contents (2%), and helped to focus on lessons (2%). However students did mentioned to the weaknesses of the video clips. They mentioned that the video clips were too fast (2%) and that vocabularies used in the video clips made it difficult to understand (2%). They mentioned that the video clips were too short (2%). Perhaps it would be better if could make them in movie or cartoon form (5%).

The Pearson product moment correlation coefficient test at the level of significant .05 of gender of participant and using video clips for learning concepts in atomic structure and the periodic table indicated there was no correlation between gender and the perception of using video clips. The same, the correlation result of chemistry grade of the participant students in semester 2/2548 and the use of video clips for learning concepts in atomic structure and the periodic table revealed the no correlation between chemistry grade of students and their perception of using video clips in their learning concepts of atomic structure and the periodic table. The data introduced in Table 4.22.

**Table 4.22** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of using video clips for learning concepts in atomic structure and the periodic table of school C students.

| **Video Clips** | **r** | |
|---|---|---|
| | **Gender** | **Chemistry Grade** |
| Thomson's experiment | 0.07 | 0.00 |
| Milligan's experiment | 0.01 | 0.07 |
| Rutherford's experiment | 0.13 | 0.10 |
| The electron cloud model VS Bohr's model of atomic structure | 0.13 | 0.18 |
| Excited electron and electronic spectrum | -0.02 | 0.14 |
| Ionization of elements | 0.24 | -0.24 |
| Electron affinity of negative electrons | -0.01 | -0.10 |

$p < .05$

### 5.3 Students' Perspective of Using VAST-models in Learning Atomic Structure and the Periodic Table

Students' perspective of using VAST-models for learning concepts in atomic structure and the periodic table is revealed in Table 4.23. The participant students from school C rated that the VAST-models are helpful for learning almost all concepts in atomic structure and the periodic table at more than 50% frequency. The VAST-models were indicated as very helpful for learning concepts of electron configuration (41%) and the arrangement elements into the periodic table (31%). The concepts of electron configurations and isotopes were mentioned that did not help in student's learning at 14% for both concepts. Interestingly, the concepts of electron configurations were mentioned at the highest percentage both in category very helpful and not helpful.

**Table 4.23** School C students' perspective of using VAST-models in learning atomic structure and the periodic table.

| **Concepts** | **Using VAST-models** (% frequency) | | |
|---|---|---|---|
| | **Very Helpful** | **Helpful** | **Not Helpful** |
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | 24 | 64 | 12 |
| Electron configurations | 41 | 45 | 14 |
| Isotopes | 17 | 69 | 14 |
| Arrangement elements into the periodic table | 31 | 62 | 7 |

The participant students of school C mentioned the benefits of using VAST-models in learning concepts in atomic structure and the periodic table that the VAST-models helped to visualize abstract concepts (17%), made concepts understandable more than reading and verbal description (12%), helped to make understanding of atomic structure and orbitals' arrangement (7%), made lessons fun and interesting (2%), useful for self study (2%), encouraged learning (2%), and helped to made understanding of electron configurations (2%). The weaknesses of using VAST-models were also mentioned. Students stated that VAST-models were confused (5%) and hard to understand (2%). In addition, students mentioned that the VAST-models were not enough (2%), they had to share the models during class activities which was not comfortable for inquiry.

**Table 4.24** Correlation between gender and chemistry grade in semester 2/2548 of the participant students with their perspective of using VAST-models for learning concepts in atomic structure and the periodic table of school C students.

| **Concepts** | **r** | |
|---|---|---|
| | **Gender** | **Chemistry Grade** |
| Atomic orbital's shapes and arrangement of atomic orbitals in atom | 0.14 | -0.15 |
| Electron configurations | 0.14 | -0.11 |
| Isotopes | 0.05 | -0.18 |
| Arrangement elements into the periodic table | 0.04 | -0.24 |

$p < .05$

The Pearson product moment correlation coefficient test at the significant value .05 (see Table 4.24) examined relation of gender of participant students and their perspective of using VAST-models for learning concepts in atomic structure and the periodic table. The test result indicated that there were no significant relationship between gender and perspective of using VAST-models. This was the same as the correlation result of chemistry grade in semester 2/2548 of the participant students and their perspective of using VAST-models for learning concepts in atomic structure and the periodic table. There was no relationship between chemistry grade and the perspective of using VAST-models for learning concepts in atomic structure and the periodic table.

# CHAPTER V

# CONCLUSIONS AND DISCUSSIONS

## Synopsis of the Research Study

### 1. Classroom Practice

The visuospatial models; VAST-models and the video clips were effective on teacher teaching and student learning. The discussions and experiments using VAST-models and video clips challenge students to determine the generalizations by themselves and relate the levels of representation to each other. These supported the constructivist learning theory which proposes that students actively construct new meaning themselves by interact with physical events and phenomena. Moreover, the using visuospatial models provided a chance for teacher teaching nature and limitation of models. Students needed to know that models are a simulation of theory and that no model looks exactly like the actual. The visuospatial models are not only explanatory but also exploratory; they make prediction about new observations and experiments, and serve as conjectures, explanations, didactic devices and communication vehicles. While watching the demonstrations of models done by teacher could improve students' ability to visualize, on the other hand, manipulating models could help students understand the underline concepts of visual representation. There fore the classroom practice should include both teacher demonstration and students' hands-on to provide students with opportunities to practice various representation skills for their best chemistry learning.

The ubiquity of model in the history and current practice is widely recognized; indeed it is difficult to think of science without models (Mathews, 2007). There were many researches revealed the benefits of models as aids to memory, as ways of bridging between the experience and understanding of learners and the more abstract theories of science (White and Frederiksen, 1998; Coll, 2006; Justi and Gilbert, 2006). Some models are so powerful at explaining well understood observations (Coll, 2006) e.g. Schrödinger's quantum mechanical model of atom. However, no all of the models are that ways this is the reason why recognizing a model's limitation nay serve to advance students' understanding (Bornea and Dori, 1996). Moreover, the use of models and modeling in teaching students about chemistry models is properly learning to develop students' understanding of physical modeling by learn to think in terms of models and interpret the ideas of scientists in terms of models (Coll, 2006).

## 2. Student Understanding of Concepts in Atomic Structure

The data from the concept test (see Figure 5.1) revealed that students from all the three participant schools comprehended almost every concept in atomic structure.

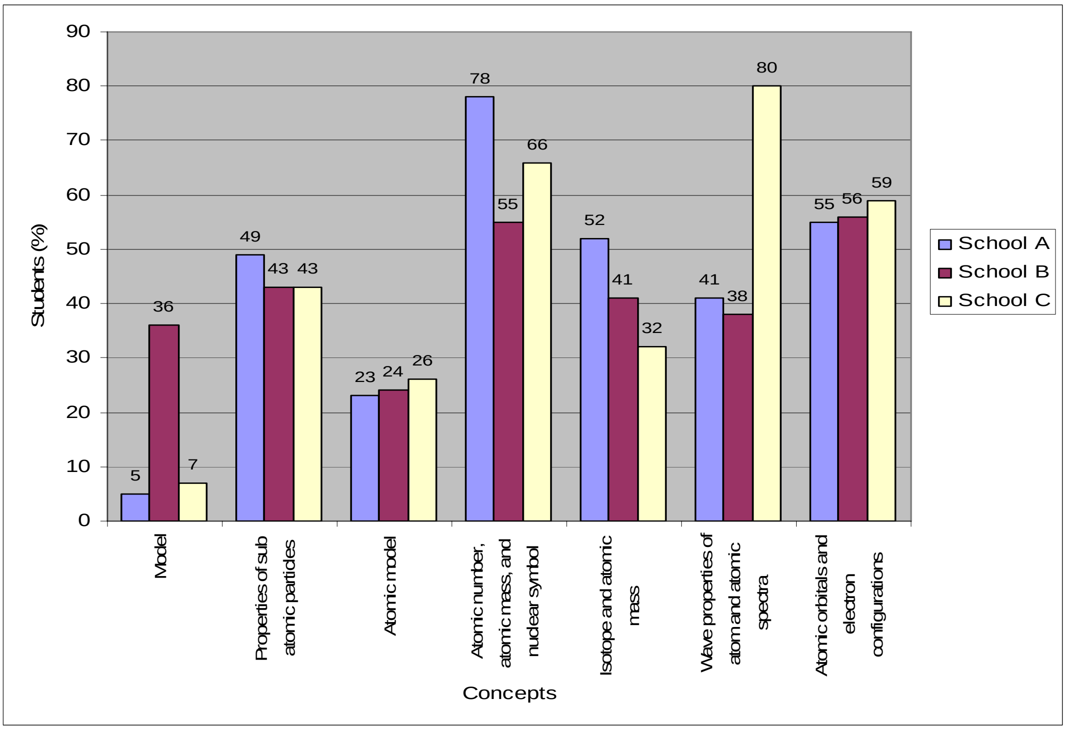



**Figure 5.1** Compared students' sound understanding concepts in atomic structure between school A, B, and C

The concepts which seem problem for student understanding were model, atomic models, and atomic number. Especially the concept of model, most of stated that model should be in a concrete from and needs an experimental result supported, the verbal statement could not be a model. This finding is conquest with the study of

Grosslight, Unger, Jay, and Smith (1991) which claimed that the novices tend to think of model in concrete term. Student's metal model of an atom found nearly the same percentages; electron cloud model of Schrödinger, planets around the sun model of Bohr and plum pudding model of Thomson. There was significant relationship of student's mental model and electron configuration. Student's mental model of electron cloud model found the most with school C students and the school C students were who did the best the concept of electron configuration in the concept test. In other hand school B students stated electron cloud model as their mental model at the least and the concept of electron configuration seems problem for them the most compared to the another two schools. Surprisingly, the concepts which involved quantitative computation (using mathematics skills) working with phenomena e.g. isotope, atomic mass, wave properties of atom, and atomic spectrum appeared not anymore a problem for students. Most of the students used the proper formula for problem solving, able to change units, and did well in mathematics calculation. Only mistake occurred was students often not used a specific unit, students preferred answer just the possessed number without mention the unit. Regards to electron configuration found Most of the students able to use both Aufbua's diagram the periodic table (noble gases), and Bohr's diagram for electron configuration. However, the periodic table was the most preferred for school A and school B students, Aufbua's diagram was the most preferred among school C students. The alternative understanding held by students were summary in Table 5.1.

**Table 5.1** The alternative understandings in atomic structure held by students from the three schools

Model

- Verbal statement is not a model.
- Models need experimental result supported.
- Models are only in a concrete form.

Properties of sub atomic particles

- Cathode rays contain positively charge.
- Cathode rays are neutral.
- Protons hold negatively charge.
- Negative particles were attracted by cathode.
- Nucleus held on charge.

Atomic model

- Negatively charged electrons stuck into a lump of positively charged proton (Thomson's atomic model).
- Most of $\alpha$ -particles were deflected at large angles because they hit the positively charge particles in the nucleus (Nucleus is large).

Atomic number, mass number and nuclear symbol

- Could not used proton number determine atom of element.
- Proton number and electron number are always equal even in ions.
- $_6X$ and $^{12}C$ were not the same element because mass of the element X could be vary.
- Could not predict the most abundance isotope from atomic mass and mass of isotopes.

- The isotope which has higher mass number is easier to find in the nature because it is bigger.

Wave properties of atom and atomic spectrum

- Used proper formula in problem solving.

Atomic orbitals and electron configuration

- Mistake in Aufbau's order of filling orbitals in electron configuration.
- Electron shifting only occurred with the complicated orbitals.
- Electron always shifting for half-filled and filled electron configuration even in the orbitals which energy level not close to each other e.g. 3*s* to 3*p*-orbital or *4s* to *4p*-orbital.
- There was no exception for the tough rule of Aufbau order, electron shifting never happen.

Atomic structure is one of the topics that students commonly find problematic and develop wide range of alternative understanding. There have been research studies to determine students' understanding and alternative conceptions. The similar findings were found in numerous research studies (Schmidt, Baumgartner, and Eybe, 2003; Taber, 2005; Niaz, 1998). Even though not many students held alternative understanding compared to students who held sound understanding, however, these difficulties needed to eliminate from students' learning.

## 3. Student Understanding of Concepts in the Periodic Table

Students from the three participant schools held sound understanding for nearly all every concepts (see Figure 5.2).

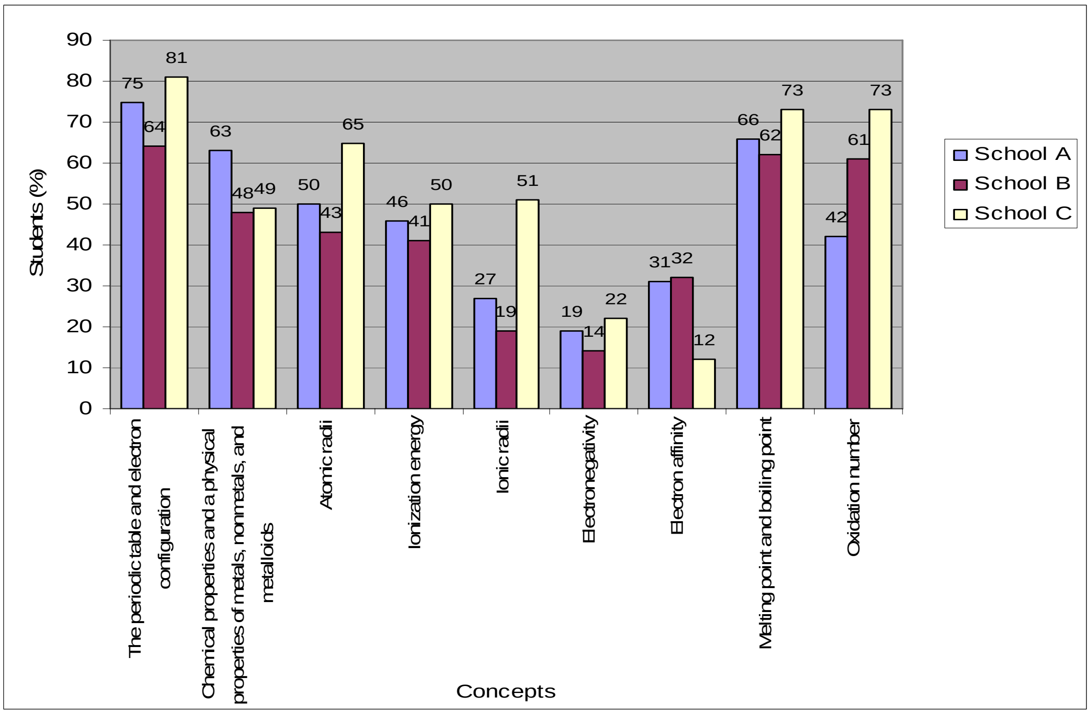



**Figure 5.2** Compared students' sound understanding concepts in the periodic table between school A, B, and C

However, there were concepts appeared difficulties for student understanding: non-metals properties, ionic radii, ionization energy, electronegativity, and electron affinity, especially electronegativity, and electron affinity seem problem for school B and school C students. Concerning concept of properties of non-metals, students remarked non-metals were all covalent molecules, in gas state, small in size, light, and held low melting point and boiling point. These appeared reasonable for students to think that way even though those are not scientific conception. Students recognized ionic radii of cations (positive ions) reduced size and anions (negative ions) gained size nevertheless over looked effect of protons in the nucleus, the important of effective nuclear charge to the size was omitted. The ionization energy trend in the periodic table of elements was understandable for students, conversely the reasons behind that property still misery e.g. attraction force/distance between electrons and nucleus, electron configurations, etc. In particular, the second ionization energy, students even thought that cations which hold half-filled and filled electron configuration will never lose anymore their electron. Regards to electronegativity, students concentrate on bonding rather electron tendency of compounds. Students gave attention to electron giving/sharing and used that idea for locating electron cloud of the compounds. For the electron affinity concept, students indicated metals never form anion. Then again, since metals prefer to be cations, if metal anions were produced, the energy could be requested to force electrons into the atom. Further more the sign of electron affinity is also confusion. Students concerned the sign +/- as mathematic symbol rather the represent of exothermic and endothermic reaction. For more the alternative understandings of students are in Table 5.2.

**Table 5. 2** The alternative understandings in the periodic table held by students from the three schools

Chemical properties and physical properties of metals, nonmetals, and metalloids

- Compared two atoms, the bigger atom is more stable.
- Compared two atoms, the smaller atom is more stable.
- The two extra electrons of Sulfur ion cause Sulfur ion less stable compared to Sulfur atom.
- The same element has the same properties either in form of atom or ions.
- Covalent molecules are gases.
- The light nonmetal atoms are floatable as gases.
- At higher energy levels electrons of metalloid form metal bonding.
- Covalent molecules have no conductivity.
- Noble gases are stable because they hold strong attractive nuclear charge.
- Noble gases are stable because they are very small in size.

Atomic radii

- The smallest atoms are in group IA
- Orbital 3*s* filled two electrons so atom of $3s^1$ is the smallest in the period.
- Could not predict atomic radii by using electron configuration.

Ionization energy

- Amount of attraction force between an electron and the nucleus depends on the number of protons presented in the nucleus and the distance of the electron from the nucleus. It does not depend on how many electrons presented, although electrons do repel each other.
- The electron which is removed will take away the attraction of the nucleus with it when it leaves the atom'
- $Na^+$ will never lose anymore electron of its stable/noble gas configuration.
- $IE_1$ depends on size of elements, the bigger elements contain greater $IE_1$.
- Ions which have the same electron configuration, the lower protons ion is smaller in ionic radii.
- Ions which have the same electron configuration have the same ionic radii.

Electronegativity

- Bigger atoms have greater electronegativity.

Electron affinity

- To add electron to metal atoms require pushing energy because metals prefer to be cations.
- Positive electron affinity need for cations forming.
- The electron affinity of exothermic reaction is positive value.
- It is impossible to form metal anions.
- Negative electron affinity mean energy required for the reaction is less than zero.

**Table 5. 2** (Continued)

Melting point and boiling point

- The small size metals have low melting point and boiling point because they are low in mass so need not much energy for breaking out their crystals.
- Could not compare melting point and boiling point of the different elements.

Oxidation number

- Oxidation number of element equal oxidation number of the compound which the element composed.
- Oxidation number of element is zero even in the compounds.
- Single atom in compounds holds oxidation number +1.
- The same element always holds the same oxidation number.
- Oxidation number of S in $H_2SO_4$ and $SO_2$ are equal because both compounds contain one atom of sulfur the same.

Not surprisingly that the participant students faced problem in learning concept the chemical periodicity of Elements. This topic was intimation problem for students along the world (Nicoll, 2001; Schmidt et. al., 2003). The concepts of electronegativity, ionization energy, and electron affinity were especially, again, albeit no many students held alternative understanding of this concept. Their conception of chemical periodicity of the elements will be affected their learning about chemical bonding, the anther topic which found crucial alternative understanding (Ozmen, 2004). Therefore, it is important to help students get over this difficulty.

## 4. Student Visuospatial Thinking

The results have shown that visuospatial thinking affected to student performance and ability to communicate scientific concepts in effective way. Visual assistance is necessary to enhance students' abilities to conduct mental model, as the finding, video animation helped student performed better in activities compared to the concepts used only lectures and textbooks. As well as the concrete three-dimensional atomic structure, VAST-models improve students understanding underlying concepts of visual representation. These evidently proved the visuospatial models indeed facilitate students to understand concepts and phenomenon behind concepts. Moreover, students could achieve a deeper understanding by using multiple visual representations e.g. using "Flame Test" experiment alone with the video clips "State of Electron According to The Bohr's Atomic Model". Obviously, visuospatial abilities were trainable. The concepts which found students held high visuospatial abilities were usually the concepts that the teacher demonstrated multiple level of representations and needed students to make a transition between them e.g. the Bohr's atomic model and atomic spectrum with students were experienced both an experiment and a video clip.

The link between visualization and chemistry learning is well established (Gilbert, 2005; Wu and Shah, 2004). Chemistry is a visual science (Wu and Shah, 2004), visualization have been used for communicating concepts to students of chemistry students' conceptual understanding might be enhanced using compared visual features of multiple representations. Moreover, the multiple representations might also help students who differ in visuospatial abilities understand specific concept (Dechsri, Heikkinen, and Jones, 1997) student visuospatial abilities therefore important for learning chemistry as a powerful skill to master knowledge in chemistry.

**5. Student Perspective of an Atomic Structure and the Periodic Instructional Units Using Visuospatial Models**

Students from all of participant schools felt knowledgeable with most concepts in atomic structure and the periodic table. The concepts which were often mentioned as little knowledgeable were in line. The students from the three participant schools agreed that the concepts which involved calculation such as atomic mass and atomic spectrum and the concepts of chemical periodicity of the elements. The concepts of chemical periodicity usually mentioned were electronegativity and electron affinity. Chi-Square test data of the understanding level for concepts in atomic structure and the periodic table not relate to gender of participant students from all three participant schools but did relate to chemistry grade of them. The concept that showed the relationship was atomic spectrum and energy calculation.

The perspective of students for using visual spatial models form all of the three participant schools was again revealed the same, useful. The video clip of Rutherford's experiment was highest mentioned that very useful for learning. The VAST-models were indicated that very useful for learning concept of electron configuration, shape of atomic orbital and their arrangement in atom, and the arrangement of elements into the periodic table. However, the result form Chi-Square test showed no relation of students' perspective of using visual spatial models with both gender and chemistry grade for all of the participant schools.

Many benefits of using visual spatial models have been indicated;

- Helped to visualize abstract concepts
- Made concepts understandable more than reading and verbal description
- Encouraged students' learning and made the lessons interesting

The weaknesses of using visual spatial models have been indicated;

- Vocabulary used in the video clip was hard to understand
- The video clips were short, it would be better if could make it in movie or cartoon
- The hands-on VAST-models were insufficient

## Recommendations

### 1. Recommendations for Using Visuospatial Models, VAST Models, and Video Clips for Teaching and Learning Chemistry

The visouspatial, VAST-models, and video clips were developed in order to aid the information of visualization of what happening at the macro level and developed students' visuospatial thinking. To introduce these visuospatial models into classroom, teacher should concern the intellectual demand of moving between modes and sub-modes of representations and emphasize a transition making between the three levels of representation; macro, submicro, and symbolic levels. The visuospatial model could use to support students' laboratory practices shifting discussion from the physical aspect of the experiments that they conduct to the chemical entities that underlie the physical phenomena. Students benefit the most from opportunities to build their own visual representations of domain concepts and phenomena in activities.

**2. Recommendations for Further Research**

Research study on enhancing student understanding concepts in chemistry has propelled chemistry teaching and learning along the journey by answering some questions. The study of models and visualization in chemistry teaching has a long history, however, there are some research questions should be possible to build on chemistry. Research questions of the integration of visualization into learning systems may suggest are about the treatment of visualization is given in IPST science curriculum at different grade levels, the effects of students preferred mode of representation or students' capabilities for visualization and their chemistry learning, and teachers' knowledge of and skills in visualization as well as models' teaching.

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# APPENDICES

## APPENDIX A

Atomic Structure and the Periodic Instruction Survey Questionnaire

**ATOMIC STRUCTURE AND THE PERIODIC TABLE**
**INSTRUCTION SURVEY QUESTIONNIRE**

**Purpose**

The atomic structure and the periodic table instruction survey questionnaire aimed to survey students' perception concerning relative understanding of; and the using video clips and VAST-models for learning; concepts in atomic structure and the periodic table.

**Description**

1. The questionnaire was divided into 4 parts (4 pages)
   - Part 1: Personal information
   - Part 1: Relative understanding of concepts in atomic structure and the periodic table.
   - Part 3: The using of video clips in atomic structure and the periodic table instruction.
   - Part 4: The using of VAST-models in atomic structure
2. Please answer the truth, as you were feeling.
3. Please answer in every item.
4. Your answer will be kept in secret and used for only this study

**-THANK YOU FOR YOUR PARTICIPATION-**

**Part 1 Personal Information**

**Gender** ☐ Male ☐ Female

**School**.......................................................................................................................................................

**Chemistry Grade in the last semester (2/2548)**.............................................................................

**<u>Part 2</u> Relative Understanding of Concepts in Atomic Structure and the Periodic Table**

*Description:* Mark / in the box which fit your feeling. How you now feel about your knowledge concerning?

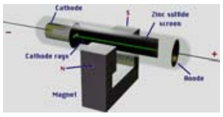
| **Topic** | **Concepts** | **Level of Understanding** | | | |
|---|---|---|---|---|---|
| | | **Very Knowledge able** | **Knowledge able** | **Little Knowledge** | **Confuse** |
| Atomic Structure | History of atomic structure study | | | | |
| | Properties of sub atomic particles | | | | |
| | Nuclear symbol, atomic number, and mass number | | | | |
| | Isotope | | | | |
| | Atomic mass and calculation | | | | |
| | Atomic spectrum and energy calculation | | | | |
| | Quantum numbers and orbitals | | | | |
| | Electron configurations | | | | |
| The Periodic Table | The development of the periodic table | | | | |
| | The arrangement of element into the periodic table | | | | |
| | Trend of atomic size in the periodic table | | | | |
| | Trend of ionization energy in the periodic table | | | | |
| | Trend of electronegativity in the periodic table | | | | |
| | Trend of electron affinity in the periodic table | | | | |
| | Trend of melting and boiling point in the periodic table | | | | |
| | Trend of oxidation numbers in the periodic table | | | | |

**<u>Part 3</u> The Using of Video Clips in Atomic Structure and the Periodic Table Instruction**

*Description:* Mark / in the box which fit your feeling. Please indicate your opinion about each video clip listed below by circling your response.

1. Thomson's Experiment

☐ Very Helpful ☐ Helpful ☐ Not Helpful

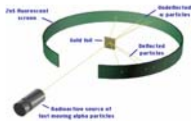


2. Milligan's Experiment

☐ Very Helpful ☐ Helpful ☐ Not Helpful

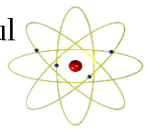
3. Rutherford's Experiment

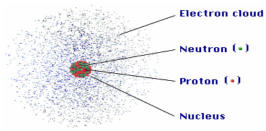
☐ Very Helpful ☐ Helpful ☐ Not Helpful



4. Bohr's Planetary and Schrodinger's Electron Cloud Models

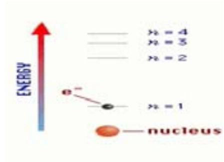
☐ Very Helpful ☐ Helpful ☐ Not Helpful





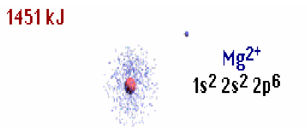

5. Electronic Spectrum and Excited Electron

☐ Very Helpful ☐ Helpful ☐ Not Helpful



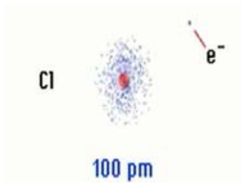

6. Ionization Energy

☐ Very Helpful ☐ Helpful ☐ Not Helpful




7. Electron Affinity

☐ Very Helpful ☐ Helpful ☐ Not Helpful




In your own words, please summarize in a few sentences, your overall opinion about using video clips in learning chemistry.

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**<u>Part 4</u> The Using of VAST-models in Atomic structure and the periodic table instruction**

*Description:* Mark / in the box which fit your feeling. Please indicate your opinion about using the VAST-models to learn atomic structure by constructing and studying electron orbitals.

1. Orbitals Shape and Orbitals Arrangement of Each Energy Level in Atom
   ☐ Very Helpful ☐ Helpful ☐ Not Helpful

2. Electron Configuration
   ☐ Very Helpful ☐ Helpful ☐ Not Helpful

3. Isotope
   ☐ Very Helpful ☐ Helpful ☐ Not Helpful

4. Arrangement Elements into the Periodic Table (specify group and period)
   ☐ Very Helpful ☐ Helpful ☐ Not Helpful

In your own words, please summarize in a few sentences, your overall opinion about using VAST-models in learning chemistry.

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-YOU ARE CHEMIST-

**APPENDIX B**

Atomic Structure and the Periodic Table Concept Test

**1st Semester Midterm Test**
**Advance Chemistry I**

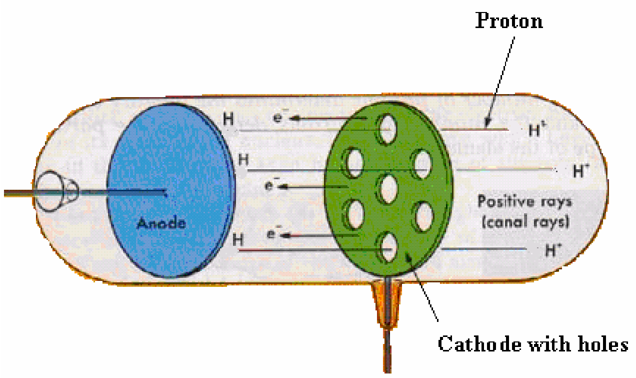
**(ATOMIC STRUCTURE AND THE PERIODIC TABLE CONCEPT TEST)**

**Description:**
1. The test included 40 questions, 20 total score.
2. Each question has 2 parts, please answer both.
3. Please marks _X_ the letter corresponding with the "*best"* answer.
4. Please show you problem solving in the question numbers: Q13-Q16 and Q20.

1. Manee said "Democritus does not have atomic model" Do you agree with her?
   A. Agree.
   B. Disagree.

   *Reason:*
   1. He stated that "matter is composed of fundamental particle called 'atom'. An atom is invisible and indestructible".
   2. He did not perform an experiment to prove his idea.
   3. He did not have any object model.

2. Carefully observe the figure following, determine the direction of protons.




   A. Toward anode.
   B. Toward cathode.
   C. I do not know.

   *Reason:*
   1. Protons have negatively charge, anode has positively charge.
   2. Protons have positively charge, anode has negative charge.
   3. Protons have negatively charge, cathode has positively charge.
   4. Protons have positively charge, cathode has negatively charge

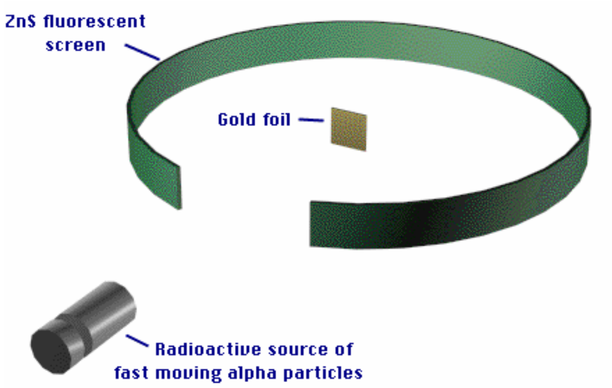
3. Thomson concluded that cathode rays composed of ……..
   A. Positively charge.
   B. Negatively charge.
   C. No charge.

*Reason:*
   1. Cathode rays deflected by electric and magnetic field.
   2. Cathode rays are attracted to anode that has positive electrical charge.
   3. Cathode rays are attracted to anode that has negative electrical charge.
   4. Cathode rays travel in straight-line paths.

4. How do you expect shooting the α-particles to neutrons
   A. Nearly all of the α-particles passed through the foil with no deflection.
   B. Nearly all of α-particles passed through the foil with a little reflection.
   C. Nearly all of α-particles passed through the foil reflect as large angle.

*Reason:*
   1. Nucleus has no charge.
   2. Nucleus has high positive charge.
   3. Nucleus has mass.

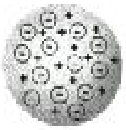
5. The figure demonstrates Rutherford's experiment.

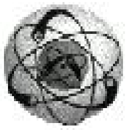



What will happen?
   A. Nearly all of the α-particles passed through the foil with no deflection.
   B. Nearly all of α-particles passed through the foil with a little reflection.
   C. Nearly all of α-particles passed through the foil reflect as large angle

*Reason:*
   1. Atoms are primarily empty space.
   2. Atoms have negatively charges electrons stuck into a lump of positively charge material, similar to raisins stuck in the dough of 'plum-pudding'.
   3. The α-particles is deflected by a high positive charge of the atomic nucleus.

6. Which is your atomic model?

A. 

B. 

C. 

*Reason:*

1. Electron and proton are scattering regularly in the atom.
2. Electrons in an atom orbiting the nucleus in a particular path which has a fixed energy.
3. Positions of electrons in an atom present as probability of being in a particular region around the nucleus.

7. What is atomic number?
   A. Number of neutrons.
   B. Number of protons.
   C. Number of electrons.

*Reason:*

1. Neutrons are in the atomic nucleus and difficult to move it out. This is the reason why we use them as a standard atomic number.
2. Element change when atom losses or gains protons.
3. Number of electrons in the neutral atom equal to number of protons.

8. Which atomic particles cause the mass of an atom?
   A. Electrons and protons.
   B. Electrons and neutrons.
   C. Protons and neutrons.

*Reason:*

1. Electrons have no mass.
2. Electrons are always moving so can not weight them.
3. Electrons are very light compared to protons and neutrons.

9. What is nuclear symbol of an element which has 18 electrons?

A. ${}^{40}_{18}X$

B. ${}^{40}_{18}Ar$

C. ${}^{18}_{40}X$

D. ${}^{18}_{40}Ar$

*Reason:*

1. Nuclear symbol is ${}^{A}_{Z}X$ , where X = element, A=mass number, Z =atomic number. However, do not have enough information to determine the element so place it as X.
2. Nuclear symbol is ${}^{A}_{Z}X$ , where X = element, A=mass number, Z =atomic number. Argon has 18 protons and 22 neutrons.
3. Nuclear symbol is ${}^{Z}_{A}X$ , where X = element, A=mass number, Z =atomic number. However, do not have enough information to determine the element so place it as X.
4. Nuclear symbol is ${}^{Z}_{A}X$ , where X = element, A=mass number, Z =atomic number. Argon has 18 protons and 22 neutrons.

10. Are ${}_{6}X$ and Carbon-12 the same element?

A. Yes.

B. No.

C. I do not know the answer.

*Reason:*

1. Isotope is the same element which has different mass number but X may not carbon.
2. Mass of element X can be varies.
3. Both of them are carbon.

11. How many protons of $S^{2-}$?

A. 14

B. 16

C. 18

*Reason:*

1. Proton number and electron number are the same.
2. Proton number of element could not change.
3. Sulfur gains 2 electrons.

12. Which isotope of copper is more abundant: copper-63 or copper-65? (the atomic mass of copper is 63.456)

A. copper-63.

B. copper-65.

C. I do not know the answer.

*Reason:*

1. The relative abundance is reflected in atomic mass.
2. The heaviest isotope is easier to find out in natural.
3. There is not sufficient information.

13. Boron has two natural isotopes. The isotope with a mass of 10.012 amu ($^{10}B$ ) has a relative abundance of 19.91%. The isope with a mass of 11.009 amu ($^{11}B$ ) has a relative abundance of 80.09%. Calculate the atomic mass of this element.

A. 10.810 amu.
B. 10.180 amu.
C. 11.018 amu.
D. 11.108 amu.

Show your solution work.

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14. Calculate the wavelength of the yellow light emitted by a sodium lamp if the frequency of the radiation is $5.10 \times 10^{14}$ Hz.

A. $5.10 \times 10^{-14}$ cm.
B. $5.76 \times 10^{9}$ nm.
C. $5.88 \times 10^{-7}$ m.
D. $5.92 \times 10^{-3}$ km.

Show your solution work.

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15. Calculate the energy of a quantum of radiant energy with a wavelength of 500 $A^0$.

A. $1.76 \times 10^{-14}$ J.
B. $3.98 \times 10^{-18}$ J.
C. $4.35 \times 10^{-14}$ J.
D. $5.54 \times 10^{-18}$ J.

Show your solution work.

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16. What is an electron configuration of element which has 45 protons? Show your solution work using;

1. Aufbau's diagram.

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2. The periodic table (noble gases)

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17. Electron configuration of bromine is [Ar] $3d^{10}4s^{1}4p^{6}$.

A. Yes.
B. No.
C. I do not know the answer.

*Reason:*

1. Electron of 4*s* orbital move to 4*p* orbital make filled electron configuration which is more stable.
2. The electron configuration of bromine should be [Ar] $4s^1 3d^{10} 4p^6$.
3. This will never happen because electrons have to enter orbitals of lowest energy first.
4. *p*-orbital is not complicated enough to cause electron splitting.

18. Electron configuration of Chromium is [Ar] $4s^1 3d^5$.

    A. Yes.
    B. No.
    C. I do not know the answer.

*Reason:*

1. Electron of 4s orbital move to 3d orbital make half-filled electron configuration which is more stable.
2. This is the exception for only the transition elements because their valence electrons were in n*s*-orbital and (n-1)*d*-orbital. So electrons of n*s* and (n-1)*d* able travel to each other.
3. The electron configuration of chromium should be [Ar] $4s^2 3d^4$.

19. Electron configuration of silicon is [Ne] $3s^1 3p^3$.

    A. Yes.
    B. No.
    C. I do not know the answer.

*Reason:*

1. Electron of 3*s*-orbital move to 3*p*-orbital composed half-filled electron configuration which is more stable.
2. 3*s*-orbital and 3*p*-orbital are in the same energy level, so their electrons able to travel to each other.
3. *p*-orbital is not complicated enough to cause electron splitting.

20. The element has mass of 114.82 amu., 49 electrons. Determine the element and predict group/period its belong in the periodic table?

    A. Zinc, group 2B, period 4.
    B. Cadmium, group 2B, period 5.
    C. Scandium, group 3B, period 4.
    D. Indium, group 3A, period 5.

Show your solution work.

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21. The elements, Zinc and Rhodium, which one is more stable compared to the other?

A. Zinc.
B. Rhodium.
C. They are equal.

*Reason:*

1. Zinc has electron configuration [Ar] $4s^2 3d^{10}$, which is filled electron configuration.
2. Rhodium has bigger atomic size.
3. Both of them are transition elements, so they were not much different in properties.

22. Sulfur ion ($S^{2-}$) is more stable than Sulfur atom.

A. Yes.
B. No.
C. They are the same.

*Reason:*

1. Percent abundance of Sulfur ion in natural is more than Sulfur atom.
2. Sulfur ion has filled electron configuration.
3. Sulfur ion gain 2 more electrons thus the extra electrons increase repulsion between the electrons in its outermost shell.
4. Since they are the same element so they hold the same properties

23. Metals are ductile and malleable.

A. Yes.
B. No.
C. I do not know the answer.

*Reason:*

1. Electrons of metal bond could travel trough every single atom in metallic crystal.
2. Only massive metal elements hold ductile and malleable properties.
3. It depends on atomic size of metal elements. Only electrons of small metal atoms could travel their neighbor atoms.
4. Nothing can change protons and neutrons in the nucleus except nuclear reaction.

24. Nonmetal elements are all gases.

A. Yes.
B. No.
C. I do not know the answer.

*Reason:*

1. They all form covalent bond.
2. They are smaller, so lighter, compared to metal in the same period.
3. They have low melting point and boiling point.
4. Heavy nonmetal elements are solid.

25. Conductivity of metalloids is getting better when heated.

A. Yes.
B. No.
C. I do not know the answer.

*Reason:*

1. Electrons gain energy and move faster.
2. This could not happen because metalloids form covalent bonding not metallic bonding.
3. At the high energy level, metalloid from metal bonding.

26. What is caused noble gas stable?

A. The attraction force between positive charge in the nucleus and electron.
B. Their electron configuration.
C. Their size.

*Reason:*

1. The noble gases hold highest atomic number in the period, their effective nuclear charge is greatest, so hard to lose electron.
2. They have filled electron configuration in every orbitals of the energy level.
3. Since they are the smallest in the period, their electron can not escape from their atom.

27. Size of the element which has electron configuration $1s^22s^22p^63s^1$ is smallest in the period.

A. True.
B. False.
C. I do not know the answer.

*Reason:*

1. The smallest element in the period belongs to Group VIIA.
2. The smallest element in the period belongs to Group IA.
3. In the third period, usually the 3*s* orbital has 2 electrons, so the element which has $3s^1$ is the smallest.
4. Can not determine size of elements from their electron configuration.

Use this chemical equation to answer item no 28-29. Sodium atoms are ionized to form sodium ions as follow:

$$Na\ (g) \rightarrow Na^+\ .(g) + e^-$$

28. When electron is removed from the sodium atom, the attraction of the nucleus for the "lose" electron will be redistributed among the remaining electrons in the sodium ion ($Na^+$).

A. True.
B. False.
C. I do not know the answer.

*Reason:*

1. The amount of attraction between an electron and the nucleus depend on the number of protons present in the nucleus and the distance of the electron from nucleus. It does not depend on how many other electrons are present, although electrons do repel each other.
2. The electron which is removed will take away the attraction of the nucleus with it when it leaves the atom.
3. The number of protons in the nucleus is the same but there is one less electron to attract, so the remaining 10 electron will experience greater attraction by the nucleus.

29. After the sodium atom is ionized, more energy is required to remove a second electron from $Na^+$ ion

A. True.
B. False.
C. This should not happen as the $Na^+$ ion will never lose any more electrons.
D. I do not know.

*Reason:*

1. Remove of the second electron disturbs the stable octet structure of $Na^+$ ion
2. The same number of proton in $Na^+$ ion attracts one less electron, so the attraction for the remaining electrons is stronger.
3. The second electron is located in the shell which is closer to the nucleus.
4. The second electron is removed from a paired 2*p* orbital and it experiences repulsion from the other electron in the same orbital.

30. Fluoride ion is bigger than sodium ion

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. Negative ion is bigger than positive ion.
2. They have the same electron number so have the same size.
3. They have the same electron configuration but sodium ion has more protons.

31. How could you arrange Beryllium, Boron, Nitrogen, and Oxygen based on their first ionization energy?

A. Be>B>N>O
B. B>Be>O>N
C. N>O>Be>B
D. O>N>B>Be

*Reason:*

1. $IE_1$ generally increases moving from IA elements to VIIIA elements along the period.
2. $IE_1$ depends on size of elements, smaller elements contain greater $IE_1$.
3. Boron and oxygen tend to lose their first electron to achieve a stable noble gas configuration so $IE_1$ of Beryllium > Boron and Nitrogen > Oxygen.

32. It always takes more energy to remove a second electron from anion than from a neutral atom.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. Electric attraction force between protons and electron is increased.
2. Need more energy to move electron form the next energy level which closer to nucleus.
3. Ionization energy of each electron increasing regularly.

33. How could you arrange Beryllium, Iron, Germanium, and Tellurium based on their electronegativity?

A. Be>Fe>Ge>Te
B. Fe>Be>Te>Ge
C. Ge>Te>Fe>Be
D. Te>Ge>Fe>Be

*Reason:*

1. The biggest atom has highest electronegativity.
2. Depends on the electron configuration of elements. If they need fewer electrons to fill orbitals, they have higher electronegatibvity.
3. Depends on how many protons the elements have, more protons increase more power to attract electrons to itself.

34. What will happen when Hydrogen atom (H) bonds with Fluorine atom (F) to form HF molecule?

A. F atom attracts electrons toward itself.
B. H atom attracts electrons toward itself.
C. Electrons are in the middle between the elements.

*Reason:*

1. H atom tends to lose electron to form $H^+$ ion and F atom tends to gain electron to form $F^-$.
2. F atom has protons in nucleus more than H atom.
3. HF is a covalent molecule. H atom and F are sharing electron.

35. Metals have positive electron affinity.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. They want to be a positive ion so need energy to force electron into atom.
2. They form negative ion by releasing energy.
3. It is impossible to make negative metal ions.

36. Potassium atom receives electron to from potassium ions as follow:

$$K (g) + e^- \rightarrow K^- (g) + 48 \text{ kJ} \qquad EA = -48 \text{ kJ/mol}$$

Suda said " energy is released when gaseous potassium atom gain an electron to form gaseous potassium ion.

A. True.
B. False.

*Reason:*

1. The energy used in this reaction is least than zero.
2. Elements always release energy to form bonding and absorb energy to break down bonding.
3. This is impossible because potassium never forms $K^-$.

37. Small size metals possess low melting point and boiling point.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. They are low mass so need not much energy to break them apart.
2. Their atoms are close packed therefore need more energy to break down the crystal.
3. Metals always have high melting point and boiling point, their size is not related.

38. Melting point and boiling point of metal elements are higher than nonmetal element.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. Metallic bond of metals is stronger than covalent bond of nonmetals.
2. Metals are solid, nonmetal are gases.
3. Nonmetals in group VIA have highest melting point and boiling point.
4. Can not compare melting point and boiling point of elements in different group because they hold different bonding.

39. Oxidation number of sodium in $NaNO_3$ is zero.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. All atoms have oxidization number zero.
2. Oxidization number is equal the net charge of compounds.
3. Oxidization number of group IA is +1.
4. There is only one sodium atom in the compound.

40. Sulfurs in $H_2SO_4$ and $SO_2$ have the same oxidation number.

A. Yes.
B. No.
C. I do not know.

*Reason:*

1. The same element has the same oxidation number.
2. All atoms have oxidation number zero.
3. Both compounds contain one atom of sulfur.
4. Oxidization number of elements is vary.

**APPENDIX C**

Quality of the Atomic Structure and the Periodic Table Concept Test

## QUALITY OF THE ATOMIC STRUCTURE AND THE PERIODIC TABLE CONCEPT TEST

The atomic structure and the periodic table concept test was a two- tire multiple test included thirty five multiple choice questions (question 1-12, 17-19, 21-40) and five open-ended questions (need to show solution of problem solving, question 13-16 and 20). The concept test was applied with 129 participant students who have learned concepts in atomic structure and the periodic table.

Quality of the atomic structure and the periodic table concept test divided into quality of the whole test and quality of the test by item. Quality of the whole test was indicated by validity and reliability. Quality of the test by item was indicated by difficulty and discrimination of the test. For the validity the whole test, the atomic structure and the periodic table concept test was designed to the objective of the test which is to study students' conception of concepts in atomic structure and the periodic table. The concept test construction was under the consideration of scientists and science educators. The reliability of the atomic structure and the periodic table concept test was indicated by Cronbach alpha used statistic computation program, SPSS 15.0 version. The Cronbach alpha value 0.561 of the concept test referred that the atomic structure and the periodic table concept test was qualified.

Difficulty measurement and discrimination measurement of the atomic structure and the periodic table concept test used statistic computation program, SPSS 15.0 version. The difficulty of the test by item revealed that all item of the test was qualified. However, the discrimination of the test indicated that question number 1, 17, 34, 35, and 36 were indicated low discrimination (see Table 1).

**Table 1** The difficulty and discrimination of the atomic structure and the periodic table concept test

| Question No. | p | r |
|---|---|---|
| 1 | 0.167 | -0.030 |
| 2 | 0.742 | 0.212 |
| 3 | 0.621 | 0.333 |
| 4 | 0.152 | 0.121 |
| 5 | 0.182 | 0.303 |
| 6 | 0.333 | 0.303 |
| 7 | 0.530 | 0.697 |
| 8 | 0.697 | 0.424 |
| 9 | 0.712 | 0.333 |
| 10 | 0.394 | 0.242 |
| 11 | 0.636 | 0.545 |
| 12 | 0.409 | 0.273 |
| 13 | 0.643 | 0.558 |
| 14 | 0.582 | 0.702 |

**Table 1** (Continued)

| Test Item No. | p | r |
|---|---|---|
| 15 | 0.486 | 0.851 |
| 16 | 0.733 | 0.458 |
| 17 | 0.530 | 0.091 |
| 18 | 0.545 | 0.485 |
| 19 | 0.455 | 0.242 |
| 20 | 0.691 | 0.593 |
| 21 | 0.561 | 0.394 |
| 22 | 0.515 | 0.424 |
| 23 | 0.652 | 0.273 |
| 24 | 0.273 | 0.424 |
| 25 | 0.591 | 0.152 |
| 26 | 0.515 | 0.364 |
| 27 | 0.576 | 0.485 |
| 28 | 0.636 | 0.485 |
| 29 | 0.667 | 0.485 |
| 30 | 0.288 | 0.273 |
| 31 | 0.197 | 0.212 |
| 32 | 0.742 | 0.152 |
| 33 | 0.303 | 0.242 |
| 34 | 0.258 | -0.030 |
| 35 | 0.333 | -0.121 |
| 36 | 0.455 | 0.000 |
| 37 | 0.606 | 0.606 |
| 38 | 0.803 | 0.273 |
| 39 | 0.545 | 0.182 |
| 40 | 0.667 | 0.364 |

The result from validity measurement, reliability measurement, difficulty measurement, and discrimination measurement indicated that the atomic structure and the periodic table concept test was qualified to use for examine students' conception.

**APPENDIX D**

Example of the Atomic Structure and the Periodic Table Instructional Units (ASPTUs)

# Lesson Plan 3

**Fundamental Chemistry**
**Grade 10th** **1st Semester, 2006**
**Unit: Atomic Structure** **2 periods (100 minutes)**
**Topics:**

- **Nuclear Symbol**
- **Atomic Number**
- **Mass Number**
- **Isotope**
- **Atomic Mass**

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**Objective: The student will -**

1. Determine atomic number and atomic mass from nuclear symbol.
2. Understand and be able to use VAST-Models to explain the relationships of atomic number, mass number, and isotope.
3. Calculate atomic number, mass number.
4. Describe various isotopes and their compositions.
5. Calculate atomic weight from isotope abundance.
6. Use VAST-Models to represent atomic structure and collect data to share with peers in evaluating the use of models in understanding atomic structure.

**IPST Science Standard**

**Sub-strand 3: Matter and Properties of Matters**

**Standard Sc 3.1:**

The student should be able to understand properties of matters, relationship between properties and structure and forces among particle, have skill in investigative processes and possess a scientific mind, communicate acquired knowledge and make positive application of knowledge.

**Level Standards Grade 10-12**

Search for information, discuss, and explain the structure of the atom, kind, and number of elementary particles of atom from nuclear symbol of elements, analyze and compare electron in the outermost shell for their manifestation in terms of properties of the elements and their reactions.

**Concept**

Atomic number is identified by the number of protons in an atom of an element. Mass number is determined by the number of neutrons and protons in the nucleus of an atom. Isotopes of elements have the same atomic number, but differ in atomic mass because the number of neutrons of an element varies. Atomic weight is based on the relative mass of 1/12 mass of carbon-12. The unit of atomic weight is atomic mass unit and its symbol is amu.

**Teaching processes**

**Introduction**

Teacher and students review the Lesson 3 together by using the "Atomic Structure" Worksheet Part A. (10 minutes)

**Teaching**

1. Using the power point presentation, the teacher should explain and lead a discussion during the lesson. The students need to think about the concepts related to atomic structure in the lesson and discuss and calculate answers to questions during the presentation. (20 minutes)
2. Students do work sheets Atomic Number and Mass Number, and Isotopes (10 minutes).
3. Students work with VAST-Model to determine atomic number, mass number, and isotope by using Exploring VAST-Models for the Atomic Structure of Elements. (15 minutes)
4. Students do activity: "The Atomic Mass of Candium" in groups of 2-3 persons. Students present what they find out and let them discuss their results. (25 minutes).

**Summarization** (10 minutes)

Teacher asks students to go back to "Atomic Structure" Worksheet Part B. Students discuss their answers together.

**Assessment** (10 minutes)

Students review their own concept map and add concepts of atomic number, mass number, isotope, and atomic mass that they have learned followed by a discussion of what they have learned.

**Assignment**

Students read Chapter One on Wave Properties and Electromagnetic Radiation of Atomic Spectra.

**Name……………………………………………..**

# Atomic Structure

**A. Identify which scientist is responsible for the following statement.**

| | | | |
|---|---|---|---|
| **a) Democritus** | **b) Dalton** | **c) Thomson** | **d) Goldstein** |
| **e) Rutherford** | **f) Chadwick** | **g) Bohr** | **h) Schrödinger** |

**i) Millikan**

_____1. Discovered neutrons.
_____2. Discovered that atoms contain negative charged particles.
_____3. His discovered proved the existence of subatomic particles.
_____4. Found that protons have mass, but electrons do not have much mass.
_____5. Discovered that the atom is mostly empty space.
_____6. Described atoms as indivisible and indestructible.
_____7. The 'gold-foil' experiment.
_____8. Described electrons as being in energy levels around the nucleus.
_____9. Developed 5 principles that compose the atomic theory.
_____10. Believe that electrons were spread trough out a positive charge atom.

**B. Fill the blanks with the correct term or phrase.**

11. The center of an atomic is called the ____________________.
12. The nucleus of an atom has a _________________charge although the atom itself is_________________.
13. The atomic number give the number of ________________ in an atom.
14. The atomic mass tell the number of ____________________.
15. An atom has 13 protons, 13 electrons, and 24 neutrons.
    a) What is the atomic mass of this atom? ____________________
    b) What is the atomic number of this atom? __________________
    c) What is the name of this atom? _________________________

**Tell if the following statements describe protons (P), electron (E), or neutron (N) by writing the correct letter(s) on the spaces. More than one letter may go on a blank.**

_______ 16. has a negative charge

_______ 17. has no charge

_______ 18. has mass of 1 amu.

_______ 16. has practically no mass

_______ 20. has a positive charge

_______ 21. located in the neucleus

_______ 22. located in the cloud around the nucleus

_______ 23. move very fast

**Use the periodic table to complete this table**

| Element | Mass Number | Atomic Number | Protons | Electrons | Neutron |
|---|---|---|---|---|---|
| Si | | | | | 15 |
| | 2 | | 1 | | |
| | 50 | | | 24 | |
| | 88 | 38 | | | |

**Three isotopes of oxygen are listed below. Determine how many protons, neutrons, and electrons are in each atom.**

| Element | Protons | Electrons | Neutrons |
|---|---|---|---|
| Oxygen-16 | | | |
| Oxygen-17 | | | |
| Oxygen-18 | | | |

**Write the nuclear symbols for the isotopes of the uranium with the follow numbers of neutrons:**

**a) 142 neutrons** **b) 143 neutrons** **c) 146 neutrons**

___________ a

___________ b

___________ c

**Name: ________________________________**

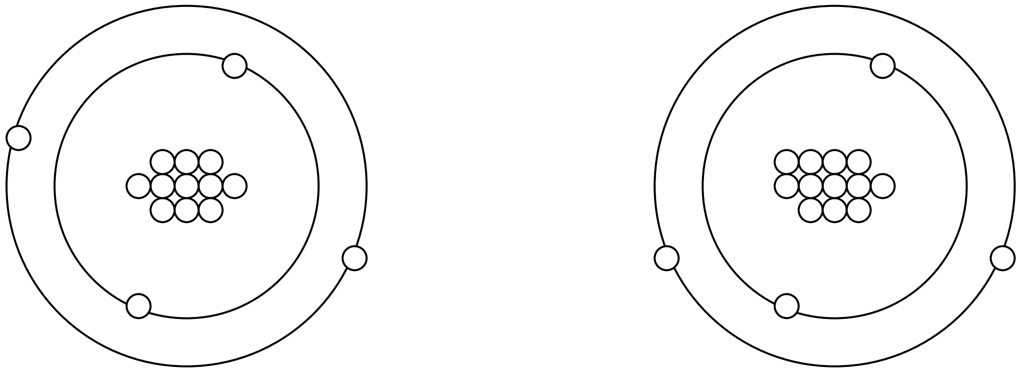
**Exploring 3D Models for the Atomic Structure of Elements**

| Model # | Electron Configurations | Electron #s | Proton #s | Neutron #s | Atomic # | Isotope | Element Name | Element Symbol |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |

**Name……………………………………………..**

# Isotopes

1. Find carbon on the periodic table.
2. For an atom to be a carbon atom, it must have six _______________
3. However all of the carbon atoms are not exactly alike. Some may have more or less <u>neutron</u> than other.
4. Atom of the same element that have different numbers of neutrons are called _________________.
5. Use the drawing of the atom below to fill in the chart. Do not use your periodic table.



A B

| Questions | atom A | atom B |
|---|---|---|
| How many protons are in the atom? | | |
| What is the name of the atom? | | |
| How many neutrons are in the atom? | | |
| What is the mass number of the atom? | | |

1. Are atoms A and B the same element?_______ How do you know? ____________________________________________________________

2. How are atom A and B different? _____________________________

3. All carbon atoms have ____________ protons.

4. Some carbon atoms (alike atom A) have _____________ neutron and a mass number of ___________________________________
5. Some carbon atoms (alike atom B) have _____________ neutrons and mass number of ___________________________________
6. Explain why the atomic mass of an element on the periodic table is not written as a whole number (why do they all have a decimal in the number??)
____________________________________________________________
____________________________________________________________

**Name………………………………………………..**

# The Atomic Mass of Candium

**Purpose:**

To analyze the isotopes of candium and to calculate its atomic mass.

**Material:**

- 3 samples of candium
- Balance
- Pencil
- Paper

**Procedure:**

Obtain a sample of candium. Separate the three isotopes (m&m's, Skittles, and Reese's Pieces) and measure the mass of each isotope. Count the numbers of m&m's, Skittles, and Reese's Pieces. Record your data in the table

| | m&m's | Skittles | Reese's Piece | Total |
|---|---|---|---|---|
| Total mass (grams) | | | | |
| Number | | | | |
| Average mass (grams) | | | | |
| Percent abundance | | | | |
| Relative abundance | | | | |
| Relative mass | | | | |

**Analysis:**

Use the experimental data, record the answers to the following questions.

1. Calculate the average mass of each isotope by dividing its total mass by the number of particles of the isotope. Record your data.

2. Calculate the percent abundance of each isotope by dividing its number of particles by the total number of particles and multiply by 100.

3. Calculate the relative abundance of each isotope by dividing the percent abundance from step 2 by 100.

4. Calculate the relative mass of each isotope by multiplying its relative abundance from step 3 by its average mass.

5. Calculate the average mass of all candium particles by adding the relative mass. This average mass is the atomic mass of candium.

6. Explain the different between percent abundance and relative abundance. What is the result when you total the individual percent abundances? The individual relative abundances?

_______________________________________________________________
_______________________________________________________________
_______________________________________________________________

7. The percent abundance of each kind of candy tells you how many each kind of candy there are in every 100 particles. What does relative abundance tell you?

_______________________________________________________________
_______________________________________________________________
_______________________________________________________________

8. Compare the total values for the rows 3 and 6 in the table. Explain why the totals differ and why the value in row 6 best presents atomic mass.

_______________________________________________________________
_______________________________________________________________
_______________________________________________________________

9. Explain any differences between the atomic mass of your candium sample and that of your neighbor. Explain why the difference would be smaller if larger sample were used.

_______________________________________________________________
_______________________________________________________________
_______________________________________________________________

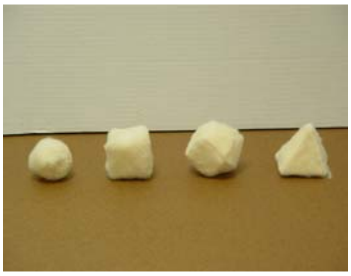
**APPENDIX E**

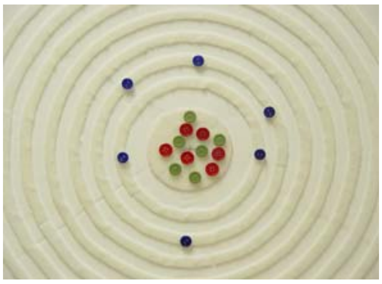
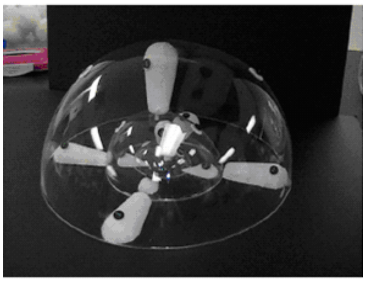
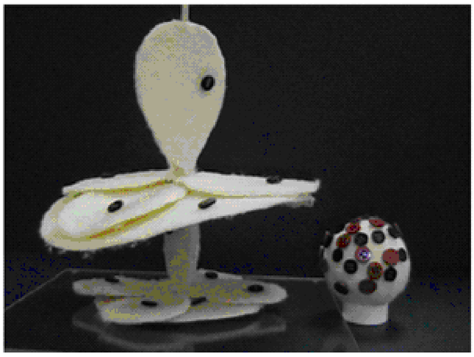
VAST-Models Teacher's Manual

# VAST-Models©

## (Visualizing Atomic Structure Through Models)

## Teacher's Manual



## About the Authors

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Panwilai Chomchid is a doctoral candidate in Science Education at Kasetsart University, Bangkok, Thailand and spent a year as a research scholar at the University of Georgia, Athens, GA. Her research interests focus on use of visualizations and modeling in teaching, learning, evaluation, and understanding chemistry. She has experience in teaching high school chemistry in Thailand and United States classrooms.

# VAST-Models (Visualizing Atomic Structure Through Models) Manual

## Preface

VAST-Models were developed based on the assumption that scientific practice is discipline specific, that chemistry instruction should be designed around key models, and that teachers and students should be able to work with and experience multiple representations for chemistry phenomena including constructing, using, revising, and critiquing models for their usefulness. Furthermore, students should be able to experience the historical development of the ideas for atomic structure in the context of the time that they each model was proposed and evaluate each for its usefulness and contribution to our understanding concepts for atomic structure and the periodic table.

VAST-Models are 3D visual representations that can be used for teaching and learning atomic structure and the periodic table, including quantum number and orbitals, atomic number, atomic mass, isotope, electron configuration, valence electrons and the positions (groups and periods) of the first 20 elements in the periodic table through inquiry. The models include two sets of materials, one set is for teacher demonstrations (Figure 1) and the second set is for students' hands-on/minds-on inquiry activities (Figure 2).

The atomic model as a quantum mechanical model estimates the probability of finding an electron in a certain position or place, Heisenberg's uncertainty principle. If we could show all positions for an electron with a specific quantized energy, the resulting picture would look something like a cloud and the VAST-Models are used to represent this electron cloud in the atom of elements.

Greek Dalton Thomson Bohr Quantum
Figure 1. VAST-Models for teacher demonstrations.

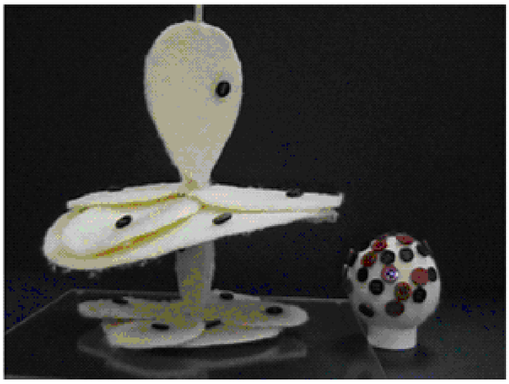


Figure 2. VAST-Models for students' hands-on learning.

**Introduction**

Using VAST-Models, we hope that teachers and students will construct and use visual 3D physical models that reflect the historical development of our understanding for atomic structure. However, we should not like to limit student's understanding of scientific models as being restricted to the actual physical models. Rather, we would like for learners to actively engage in scientific modeling. That is, a scientific model is a set of ideas that describes a natural phenomenon (Cartier, Rudolph, & Stewart, 2001):

- A scientific model is a set of ideas that describes a natural process.
- Models are constituted by empirical or theoretical objects and the processes in which they participate.
- Models can be used to explain and predict natural phenomena.
- Models are consistently assessed on the basis of empirical and conceptual criteria.
- Models are useful as guides to future research

We believe that the physical models used in VAST-Models are meant to complement teacher guided inquiry, along with textbook and supplementary readings, relevant "wet and dry" laboratory activities and experiments, and videos.

*Visualization and Modeling in Chemistry*

The role of visualization in science learning has become an important area of research as not only have theoretical frameworks emerged to provide lens through which to investigate student understandings, but visualization also offers new ways for students to engage in inquiry (Gobert, 2005). What do we mean by visualization? Currently, visualization is thought of as including three domains:

- External representations in science refer to the physical models, graphics, diagrams, PowerPoint presentations, and videos teachers typically use in the chemistry classroom.
- Internal representations refer to the mental constructs and representations students develop and use in their understanding of natural phenomena such as atomic structure. These representations may be propositional/semantic or visual forms.

- Spatial skill is the ability students have to manipulate or transform images or spatial patterns into other arrangements such as interpreting how a textbook diagram for atomic structure can be compared to a 3D physical model.

*History of the Atom*

Greek model for the atom

Some Greeks believed four elements existed: fire, water, earth, and air. Each element had a specific shape, fire was a pyramid with sharp jagged points representing pain, water was a sphere representing its ability to flow, earth was a cube to represent that it is solid and immovable, and air was a multi-sided figure representing its ability to move, but also cause disturbances as wind. For demonstration, the teacher may have the students observe and draw the different models and lead a discussion about the philosophies, assumptions, ideas, and evidence some Greeks, such as Democritus, may have used to construct their models and why other Greeks disagreed with their ideas. The Greeks did not have a model for atomic structure because the assumption was that the atom, itself, was indivisible. Similarly, their idea of the atom would not be considered to be a scientific theory because there was insufficient evidence or facts to support their models.

Dalton's model for the atom

At the time of Dalton, the most accepted model for the atom was based on the corpuscular theory of Descartes who had proposed that the properties of substances depended upon the different shapes of their atoms, similar to the Greek models. Scientists had failed to find combinations of the four elements based on the Greek model, such as the products of fire-water. However, several new elements had been identified. Other new substances had also been proposed. For example, one theory postulated that flammable materials contained a substance called phlogiston was given off during combustion. Van Helmont believed that there were only two elements, water and air. And, he conducted a well known experiment in biology demonstrating that water was essential for plant growth, whereas very little soil was used.

Dalton performed experiments to investigate how elements reacted with one another. He studied the ratios in which elements combine in chemical reactions. Based on his results, In 1808 Dalton formulated Dalton's atomic theory, which is summarized in the following list.

- All elements are composed of tiny indivisible particles called atoms.

- Atoms of the same element are identical. The atoms of any one element are different from those of any other element.

- Atoms of different elements can physically mix together or can chemically combine with one another in sample whole number ratios to form compounds.

- Chemical reactions occur when atom are separated, joined, or rearranged. Atoms of one element, however, are never changed into atom of another element as a result of chemical reaction.

Thomson's model for the atom

Thomson passed an electric current through gases at low pressure in a cathode ray tube. He found that cathode rays are attracted to the anode that has positive electrical charge. The plates that carry a negative electrical charge repel the ray. So he proposed that a cathode ray is a stream of tiny negatively charged particles moving at high speed.

Thomson proposed a revised model, referred to as the "plum-pudding" atom. The plum-pudding atom had negatively charged electrons stuck into a lump of positively charged material, similar to raisins stuck in the dough.

Rutherford's model for the atom

Rutherford had established that alpha ($\alpha$) particles are positively charged particles. They are emitted at high kinetic energies by some radioactive atoms, that is, atoms that disintegrate spontaneously. He bombarded a very thin piece of gold with $\alpha$-particles from a radioactive source. A fluorescent zinc sulfide screen was placed behind the foil to indicate the scattering of the $\alpha$-particles by the gold foil. Scintillations (flashes) on the screen, caused by the individual $\alpha$-particles, were counted to determine the relative number of $\alpha$-particles deflected at the various angles. At the time, $\alpha$-particles were believed to be extremely dense, much denser than the gold atom. Quite unexpectedly, nearly all of the $\alpha$-particles passed through the foil with little or no deflection. A few, however, were deflected at large angles, and very few $\alpha$-particles even return from the gold foil in the direction from which they had come.

Rutherford concluded that atom consist of very small, very dense positively charged nuclei surrounded by clouds of electrons at relatively large distances from the nuclei.

Bohr's model for the atom

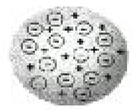
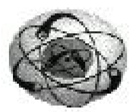
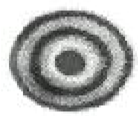
In the meantime, scientists had another question, since protons and electrons have a different charge: "Why didn't the electrons fall down or get pulled into the nucleus?" Bohr tried to answer this question. He proposed that electrons are arranged in concentric circular paths, or orbits, around the nucleus in particular energy levels and perhaps their momentum kept them in orbit. This model was patterned after the motions of the planets around the sun. Bohr proposed that electrons in a particular path have a fixed energy; the electrons do not lose energy and can not fall into the nucleus. The energy level of an electron is the region around the nucleus where electron is most likely to be moving.

Schrödinger's quantum mechanical model for the atom

Schrödinger used a new way of thinking about mathematics and used quantum theory to write and solve a mathematical equation describing the location and energy of an electron in a hydrogen atom. The modern description for electrons in atoms, the quantum mechanical model, comes from the mathematical solution to Schrödinger's equation.

In the quantum mechanical model of the atom, the probability of finding an electron is that it is located within a certain volume of space surrounding the nucleus that can be represented as a fuzzy cloud. The cloud is denser where the probability of finding the electron is high. The cloud is less dense where the probability of finding the electron is low. Although it is unclear where the cloud ends, there is at least a slight chance of finding the electron a considerable distance from the nucleus. Therefore, attempts to show probabilities as a fuzzy cloud are unusually limited to the volume in which the electron is found 90% of the time. To visualize an electron probability cloud, imagine that you could mold a sack around the cloud so that the electron was inside the sack 90% of the time. The shape of the sack would then give you a useful picture of the shape of the cloud. These cloud shapes may, for example, be spheres or dumb-bells, depending upon the energy level of the electron. Illustrations of electron clouds typically show the shape in which the electron is found 90% of the time.

**Table 1.** Historical time-line for the development of models for atomic structure.

| **Year** | **Model developed by** | **Model also known as** | **Atomic model** |
|---|---|---|---|
| 1803 – 1807 | Dalton | Billiard Ball Model |  |
| 1897 | Thomson | Plum Pudding Model |  |
| 1909 | Rutherford | Rutherford's Model |  |
| 1913 | Bohr | Planetary Model |  |
| 1926 | Schrödinger | Quantum Mechanical Model |  |

**VAST-Models Objectives:**

The VAST-Models are designed to help students understand the following chemistry concepts;

1. The historic development of our understanding of atomic structure
2. Quantum numbers and atomic orbitals
3. Atomic number, atomic mass, and isotopes
4. Electron configurations and valence electron
5. Position of elements in the periodic table

**Instructions** :

*Models for Teacher Demonstration*

*Part A. Greek model for the elements*

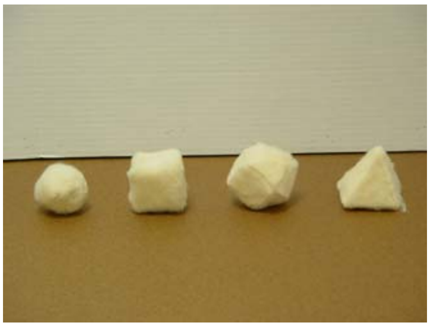


Figure 3. Greek Model (water-earth-air-fire)

*Part B. Dalton's model for the elements*

Figure 4. Billiard Ball Model

*Part C. Thomson's model for the electron*

Figure 5. Plum Pudding Model

*Part D. Bohr's model for atomic structure*

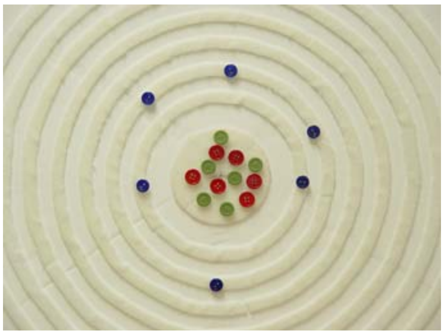


Figure 6. Planetary Model

*Part E. Quantum mechanical model for atomic structure*

1. Use a sphere model to represent nucleus of an atom

Figure 7. A nucleus

2. Use a half sphere model represent s-orbitals

Figure 8. s-orbital

3. Use a dumbbell model represent p-orbitals


Figure 9a. $p_x$-orbital


Figure 9b. $p_y$-orbital

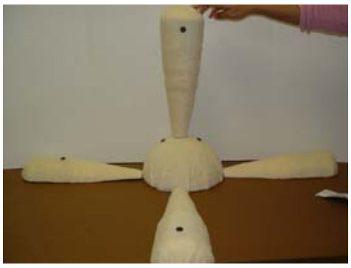


Figure 9c. $p_z$-orbital

4. Use different colors of buttons to represent protons, neutrons, and electrons. And, for electron spin the teacher needs to tell the students to use appropriate arrow directions.


Figure 10a. Protons and neutrons in nucleus

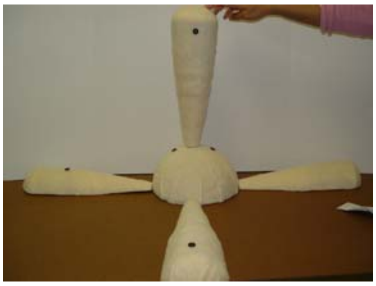


Figure 10b. Electrons in orbitals

5. Demonstration

The teacher can introduce the quantum mechanical model for the atom and quantum numbers and allow the students to calculate quantum numbers. Then, the teacher can introduce the students to using the VAST-Models representing the order of subatomic orbitals based on Aufbau diagram.

*Model for students' hands-on activity*

1. Use a sphere model to represent nucleus of an atom.


Figure 11. A neucleus

2. Fix the board and doweling as in the picture below. This can then be used for filling the atomic orbitals for each element.

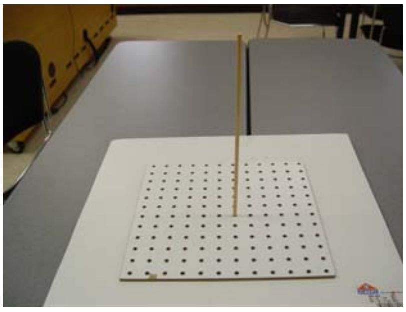


Figure 12. The stand position

3. Use a circle model represent s-orbitals.

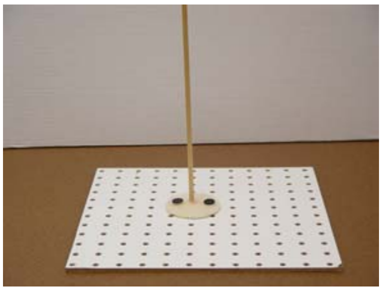


Figure 13. s-orbital

4. Use a dumbbell model represent p-orbitals

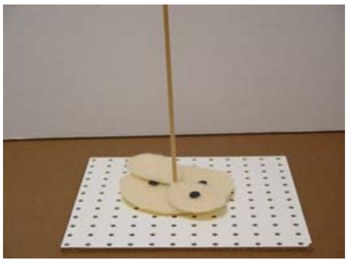


Figure 14a. $p_x$-orbital

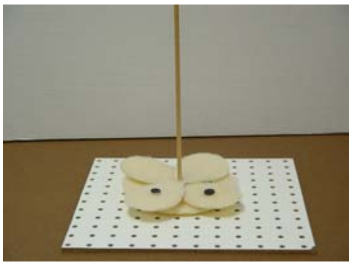


Figure 14b. $p_y$-orbital

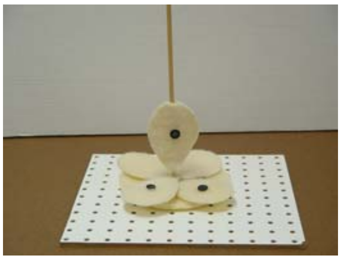


Figure 14c. $p_z$-orbital

5. Use different colors of buttons to represent protons, neutrons, and electrons. And, for electron spin the teacher needs to tell the students to use appropriate arrow directions.

Figure 15a. Protons and neutron in nucleus

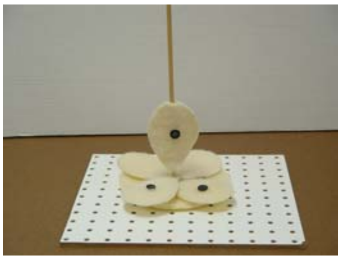


Figure 15b. Electrons in orbitals

6. Students' Hands- on Activities

Students use the VAST-Models to determine atomic properties and construct models for the atoms of the first 20 elements. Students randomly draw an element's atomic number from a cup and construct a model for that element including the neucleus and the electron orbitals. Students then exchange their models to identify all of the elements constructed in the class.

**Teaching and Learning Activities**

Table 1. Teaching and learning activites trough VAST-Models

| **Concepts** | **Using VAST-Models** |
|---|---|
| Quantum numbers and atomic orbitals | Teacher uses the VAST-models for teacher demonstration showing the relation of quantum number and shapes of atomic orbitals according to quantum numbers. |
| Atomic number | Students construct the nucleus for an element reflecting the elements atomic number and atomic mass, and including possible isotopes. |
| Atomic mass | |
| Isotope | |
| Electron configurations | 1. Teacher demonstrates how to fill electrons into atomic orbitals using an Aufbau diagram.<br>2. Students construct the electron configuration for the element they have drawn.<br>3. Students determine the valence electron(s) for the element. |
| Valence electron | |
| Position of elements in the periodic table | 1. Students use their models to determine the position of their elements in the periodic table, without using the periodic table as a direct reference.<br>2. Students use the periodic table to check their answers. If any answer is incorrect, they should determine why the inconsistency exists for their model and the periodic table. |

# CURRICULUM VITAE

**NAME** : Ms. Panwilai Chomchid

**BIRTH DATE** : July 27, 1979

**BIRTH PLACE** : Roi-Et Province, Thailand

**EDUCATION** :

| YEAR | INSTITUTE | DEGREE/DIPLOMA |
| --- | --- | --- |
| 2001 | Mahasarakham Univ. | B.Sc. (Chemistry) |
| 2002 | Mahasarakham Univ. | Grad. Dip. (Science Teaching) |

**POSSITION/ TITLE** : -

**WORK PLACE** : -

**SCHOLASHIP/AWARDS** : The Institute for the Promotion of Teaching Science and Technology (IPST) Scholarship 1998-2008