บทความวิจัย

มุมมองของครูผู้สอนวิชาเคมีระดับชั้นมัธยมศึกษาเกี่ยวกับความยากในการสอนเรื่องโครงสร้างอะตอมและตารางธาตุ: มุมมองครูไทยและครูเคนยา

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บทคัดย่อ

การวิจัยนี้มีจุดมุ่งหมายเพื่อศึกษาความคิดเห็นของครูในประเทศไทยและประเทศเคนยาเกี่ยวกับปัญหาในการปฏิบัติการสอนเรื่องโครงสร้างอะตอมและตารางธาตุ โดยใช้แบบสอบถามและการสัมภาษณ์ ผลการวิจัยพบว่าทั้งครูไทยและครูเคนยาต่างก็พบปัญหาในการสอนแนวคิดที่เกี่ยวข้องกับเนื้อหาเรื่องโครงสร้างอะตอมและตารางธาตุ

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สนับสนุนความเชื่อของผู้วิจัยที่ว่าความยากในการสอนแนวคิดเกี่ยวกับโครงสร้างอะตอมและตารางธาตุเป็นสากล ผู้วิจัยจะนำผลการศึกษาในครั้งนี้ไปใช้ออกแบบในการสร้างบทเรียนและสื่อการเรียนการสอนที่สอดคล้องกับความต้องการของครูและนักเรียน พร้อมทั้งเก็บข้อมูลผลการใช้บทเรียนและสื่อการเรียนการสอนที่จะสร้างขึ้นในครั้งนี้ด้วย

คำสำคัญ: โครงสร้างอะตอม, ตารางธาตุ, ประเทศเคนยา, ประเทศไทย, มุมมองของครูผู้สอน, วิชาเคมี

RESEARCH ARTICLE

Secondary High School Chemistry Teachers' Perspectives on the Difficulties of Teaching Atomic Structure and the Periodic Table: Views from Thailand and Kenya

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Abstract

Our research study provides a glimpse into difficulties high school chemistry teachers in Thailand and Kenya encounter in classroom practice when addressing issues of learning atomic structure and the periodic table. In this paper, we focus on chemistry teachers' reflections using surveys with questionnaires and interviews to learn about the difficulties they encounter in teaching basic concepts related to atomic structure and the periodic table in chemistry. We do not believe that teachers in Thailand and Kenya are different from those in the global community, but little data exists to support this claim especially with regard to rural areas. Our data is being used to design and create curriculum materials relevant to the teachers' and students' needs and we are planning to investigate its usefulness.

Keywords: atomic structure, chemistry, Kenya, periodic table, teachers' perspectives, Thailand

Introduction

Understanding atomic structure and the periodic table are critical for learners since these topics serve as the foundation for understanding chemistry. The topics occur early in syllabi internationally including Thailand (Institute for the Promotion of Teaching Science and Technology [IPST], 2002) and Kenya (Kenya Institute of Education [KIE], 2002). In both countries' syllabi, students are to learn atomic structure and the periodic table. Similarly, whether the syllabi are written in Thai or English, the content language for detail is nearly identical and both share low student performance in high stakes' examinations resulting in national prioritizing for addressing the needs of teachers (Montero-Sieburth, 1992). Teachers are viewed as the most important means through which students' scores may be raised and high failure rates reduced (Bureau of Educational Testing, 2004). Internationally, chemistry educators have been researching issues focused on learner's understanding of basic chemistry including visuospatial thinking (Gilbert, 2005; Wu and Shah, 2004), modeling (Coll and Treagust, 2003; Snir et al., 2003), atomic structure (Niaz. 1998; Niaz et al., 2002), and conceptual change (Nieswandt, 2001). In addition, others have explored teachers' conceptions of teaching (Haidar, 1997; Kruse and Roehrig, 2005; Sweeney et al., 2001). However, little has been published on problems students encounter in learning fundamental chemistry in Thailand (Chuephangum, 2000) and Kenya (Inyega, 2005). Teachers' views on instruction and learning atomic structure and the periodic table are non-existent. Our paper provides initial data on Thai and Kenyan teachers' perspectives on instructional strategies they implement, and difficulties they have, in teaching atomic structure and the periodic table. Our goal is to develop strategies and materials teachers can use in teaching atomic structure and the periodic table that might lead to a better understanding of fundamental chemistry principals. Understanding the concepts of Atomic structure and the Periodic table will help students to understand advanced chemistry topics. We feel this is important because issues such as global climate change, alternative energy sources, medicinal and drug use, and basic needs such as clean water all depend upon an understanding of chemistry. In addition, cultural beliefs also impact on people's perceptions of problems and their solutions (Caillods et al., 1996). Furthermore, we are interested in finding out more about how professional development impacts student learning in different cultural contexts (Garet et al., 2001; Loucks-Horsley et al., 2003; Luft, 2001).

The purposes of the study

In Thailand, the study sought to determine teachers' perspectives on (a) the relative hardness for teaching topics included in atomic structure and periodic table, (b) what problems teachers encounter in teaching these topics, (c) to rank order the frequencies of current formats the teachers currently use in teaching atomic structure and the periodic table, and (d) given a choice, to choose teaching formats the teachers would most like to use in teaching atomic structure and the periodic table. In Kenya, the study investigated chemistry teachers' practices in (a) designing and implementing the periodic table unit lessons and (b) making changes when designing and implementing the unit lessons following an In-service Education Program in Kenya.

Reaserch design

Our study is a synthesis of two independently developed research designs, a survey conducted in Thailand and interviews and observations conducted in Kenya, both with the goal of determining chemistry teachers' perspectives on the difficulty and strategies used in teaching atomic structure and the periodic table. The studies also differ in that the survey conducted in Thailand is being used to create innovative instructional strategies and materials for classroom implementation, whereas interviews in Kenya were conducted following in-service professional development with the goal that innovative instruction had been implemented. In Thailand, the survey was conducted in northeastern Thailand. In Kenya, the study was conducted in western Kenya. Data from Thailand has been translated into English by the researchers. The multi-site study conducted in Thailand included 24 chemistry teachers. The study was designed to determine teachers' perspectives on (a) the relative hardness (Scale 1- 4) for teaching topics included in atomic structure and the periodic table (b) what problems (eleven categories plus "other") they encounter in teaching these topics; (c) to rank order the frequencies of current formats (ten categories plus "other") the teachers currently use in teaching atomic structure and the periodic table; and (d) given a choice, to choose teaching formats the teachers would most like to use in teaching atomic structure and the periodic table (ten stated categories plus "other"). Each teacher could select, as many items as s/he felt was important. Also included in the survey were baseline demographic data including teaching experience (years and specifically years in chemistry), content area, and the highest level of degree attained. The multi-site qualitative case study research in Kenya included 9 chemistry teachers purposively selected in different school settings (boys' boarding, girls' boarding, mixed boarding, and mixed day) in two districts. The participants' class sizes ranged from 40 to 50 students, depending on the school category (National, Provincial or District). District schools tend to have a large number of students in class. In Kenya, secondary school science teachers teach across the forms (grades 9, 10, 11, and 12) using a national spiral model curriculum. The purpose of the workshops was to prepare teachers for incorporating locally available resources into their curriculum, instruction, and assessment. Participating teachers were interviewed and observed in their classrooms over a 2-month period, during which students have four chemistry lessons per week.

Results

Findings from Thailand

Chemistry Concepts

The Institute for the Promotion of Teaching Science and Technology (IPST) is the organization responsible for developing the science and mathematics curriculum in Thailand. In the IPST science curriculum chemistry is in the sub-strand 3 on Matter and Properties. There are 7 topics in chemistry for grade 10-12 students; structure of atom, the periodic table and compounds, chemical bonds, chemical reaction, petroleum, polymers, and biomolecules. The topic structure of atom is divided into 4 concepts: atomic models; elementary particles of atoms (subatomic particles); atomic number, mass number and isotope; and electronic configuration of atoms (electron configuration). The topic on the

periodic table and compounds is divided into four concepts: arrangement of elements in the periodic table, certain properties of elements in the periodic table, reactivities of elements in the periodic table, and tendencies of properties of elements in the periodic table (IPST, 2002). Based on the IPST science curriculum, eight chemistry concepts were asked in the questionnaire (4 in atomic structure and 4 in the periodic table).

Participants' Backgrounds

The research survey involved 26 chemistry teachers from 26 high schools in Surin Province, Educational Area 1, in Thailand. However two teachers did not respond to the questionnaire. The 24 participant teachers were comprised of 16 females and 8 males. More than one half (14/24=58%) of the teachers teach chemistry at all grade levels. One half (12/24=50%) of the teachers have experience in teaching in the 5-10 years and 29% (7/24) have teaching experiences lest than five years period range. Nearly one half (10/24=42%) of the teachers have experience in teaching chemistry for less than 5 years and the 5-10 year periods. Most of participant teachers (17/24=71%) are graduates in chemistry and nearly all of them (23/24=96%) graduated with a Bachelors' degree.

The Relative Hardness of Topics in Chemistry Teaching

The perceptions of participant teachers in teaching chemistry were surveyed with regard to their perspectives of relative hardness of topics taught in chemistry. The participant teachers said that all concepts in atomic structure and periodic table are difficult to very difficult to teach. The concepts of subatomic particle, electron configuration and chemical properties of representative compounds were frequently mentioned (Table 1).

The participant teachers stated that the concepts in atomic structure and periodic table are difficult to teach because these are abstract topics and students have to imagine a lot to construct an understanding of things that cannot be seen. The teachers seem not to possess adequate knowledge to construct their own instructional materials or models to use in teaching. And they also stated that the students are slower learners implying that they are not ready for chemistry. The following are some examples of what the teachers said:

Table 1 The relative hardness for teaching

(1= very easy, 2=easy, 3=difficult, 4=very difficult)

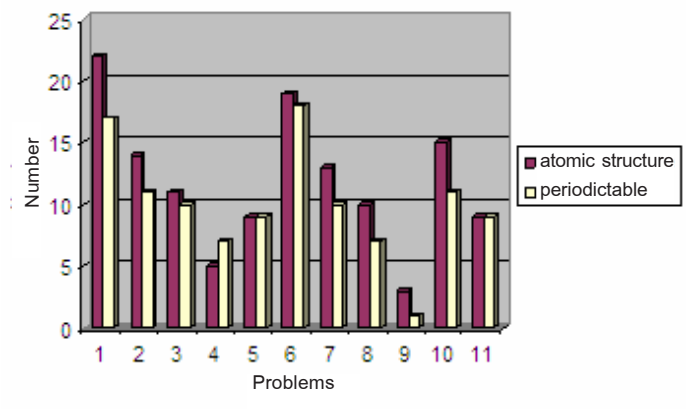
Topics		Hardness level for teaching				Sum
		1	2	3	4	
Atomic structure	Atomic models	5	1	9	9	24
	Sub atomic particles	3	0	9	12	24
	Electron configurations	5	1	11	7	24
Periodic table	Organizing of Periodic table	5	2	8	9	24
	Periodic trends	4	5	8	7	24
	Chemical properties of representative compounds	5	3	10	6	24

> ...the concept is very abstract. Students have to use their imagination to make understanding. I don't know how to make any instructional materials to help them understand the concepts better. (Teacher 1)
>
> The problem is students don't like to read and they have short memory. For example, the concepts that I taught at the beginning of a period, if I ask a question at the end of period. They can't answer, especially students in a low ability class. (Teacher 2)

They learn by memorizing (rote learning) and don't pay enough attention in constructing a meaningful learning of the topics.

Problems Teachers Encounter in Teaching Chemistry

The highest number of teaching problems that teachers encounter in teaching atomic structure and periodic table are lack of concrete instructional material, teachers have too much extra work to do, and students do not have enough basic content and skills that are important for studying in advance of a lesson (Figure 1).



Note
1. Lack of concrete instructional material
2. Loaded teaching periods
3. Lack of laboratories instruments & chemicals
4. Too many students in a class
5. Lack of textbooks & teaching guide
6. Too many extra works
7. Lack of learning sources
8. Don't have new teaching strategy
9. Chemistry contents and teaching time in the curriculum not suitable
10. Students don't have enough basic contents & skills
11. Lack of instructional instruments

Figure 1 Teaching problems participant teachers encounter in teaching

Problem solving that teachers use for these issues vary. They make up for time in the course by having extra classes for teaching fundamental concepts. As the one of the participant teachers said:

> Some subjects, such as guidance, teachers don' t often teach. I can use that period to make up the course…. if I know I can't finish the lesson in time. I will ask students to have a class at 7.15-7.45 a.m. before school activities in the morning. So at least I can teach for 30 minutes.

When teachers are unable to cover their week' s class work, they ask students to attend class on the weekend (Saturday and Sunday). Moreover participant teachers attempt to construct teaching materials by themselves or assign students to construct their own learning materials. They also assign students to do a report on their self-studies as one participant stated:

> Ask them to make a model. They create the model themselves from their own understanding. Then they present their model to the class. I will

give a reflection later... I assigned the students to make the periodic table in groups.

Frequencies of the Current Formats the Teachers Currently Use in Teaching

The teaching formats that teachers usually use to teach atomic structure and periodic table is lecture, using worksheets, students practice, and doing laboratory (Figure 2).

Preferred Teaching Formats the Teachers Would Most Like to Use in Teaching

The preferred teaching formats that teachers think they would like to use are shown in Figure 3.

The highest ranked teaching format that teachers want to use in teaching atomic structure and periodic table is that of computer assisted visual instruction. Worksheet, lecture, doing laboratory are still important. Using video is another way teachers think would be good for teaching atomic structure, and periodic table.

Findings from Kenya

In these findings, participants' pseudonyms (Moja, Mbili, Tatu, Nne, Tano, Sita, Saba, Nane, and Tisa, where applicable) are used. The findings are presented from each district (Districts One and Two). In the text "SMASSE" refers to strengthening of

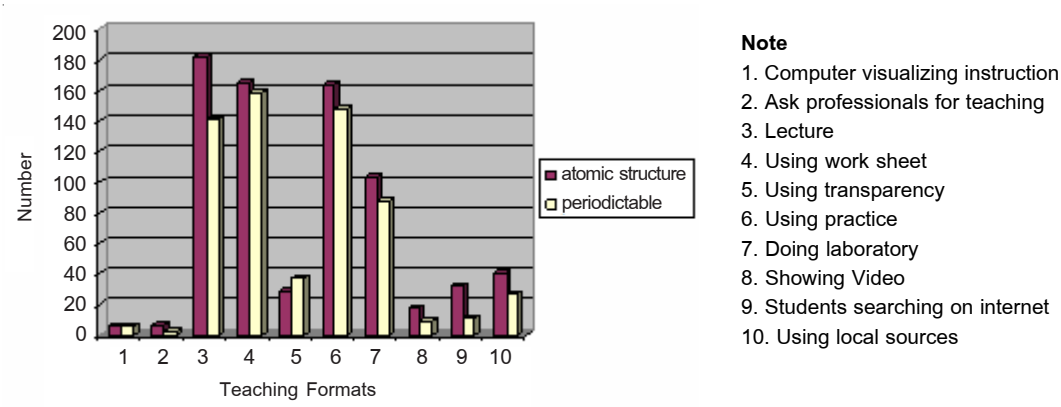


Figure 2 Teaching formats which participant teachers frequently use in teaching

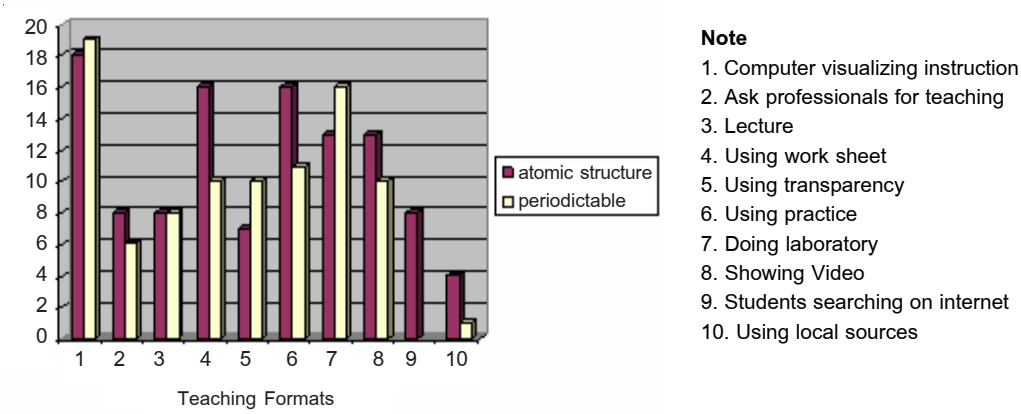


Figure 3 Preferred teaching formats which participant teachers would like to use in teaching

mathematics and science in secondary education, "ASEI" refers to activity, student-centered, experiments, and improvisation, while PDSI refers to plan-do-see-improve.

Findings from District One

Planning and Implementing Chemistry Unit Lessons

Tatu started off arguing that the topics in the secondary school chemistry curriculum are different and for one to make sure that he/she had covered the content of each topic effectively one must use appropriate teaching and learning approaches. The participants design and implement unit lessons on the periodic table. It appeared that the participants had improved their teaching practices on each of the chemistry units they were in-serviced in. Following, are the participants' experiences on the Periodic Table unit they teach.

Planning and Implementing Lessons on the Periodic Table

The in-service teachers believe that the topic on the periodic table is the core of chemistry. The learners need to understand the periodic table first before they proceed into other chemistry areas that involve chemical reactions. According to the in-service teachers, students who do not understand the periodic table well are likely to have difficulties when studying other topic areas in chemistry. For effective understanding of the periodic table by students, teachers should cover valences first, followed by chemical formulae of compounds, and then the chemical equations. Teachers have to plan for student activities when covering these areas. On the teaching of the periodic table, Tatu noted:

> It is very important to cover this topic of the periodic table thoroughly for this is actually the core of chemistry. It is in this topic we cover the valences and then later we cover about the formulae of compounds and then later also with chemical equations. Now once these areas are not well covered then the other areas of chemistry, the other topics become very difficult. So it is good to build [among] the way we have [inaudible] we used to make it concrete to have activities that students could participate into enhance their understandings.

Mbili supported Tatu's assertion on how the periodic table can be presented to students in school. As Mbili stated:

> ..something to add, especially, when you come to the valences, as he has said you know now you have done the periodic table and they have known the rows, the groups and as he said if you can use the colors I think it will help them. And so now they have known but maybe the valence and the number of the outermost electrons will be the same.

However, the students were found to have difficulties in writing the chemical formulae of ions. Mbili felt that students could be helped through use of improvised models of the electronic configurations of atoms and ions. By so doing, the learners are able to visualize and understand how positive and negative ions are formed, and why various ions have different ionic formulae. On how to assist student know how to write ionic formulae, Mbili said:

> Now sometimes I find it is difficult for a student especially to write the formula of an ion. Now sometimes the students do not understand that the protons do not take part in the reaction involving electrons. So like that one maybe you could have some model of electronic configuration and then you can have a wire and then you can pick "Plastocene" standing for electrons and then you can have a number at the center standing for protons. And so during the ion formation, you know you can decide now this one had so many, magnesium, two, then you can decide to remove the two electrons then the students will count now the electrons left to see they are ten, then the protons are the same. Then, from there you can come and tell the students because it has more positives now than the negatives, this is how you can write it. And then you can go to the other one and I think it helps because they are seeing it. They are seeing it you have removed electrons. I think I find it helping the students quite a lot and you know naturally the students like where there are those activities you find that they are moved.

Moja concurred with his colleagues on how the periodic table can be taught and how improvised models help students to understand the topic better. According to Moja, the students must first understand the atomic structure in relation to electron arrangement in atoms. Good knowledge about the atomic structure and electronic configuration in atoms helps students to understand why various elements are put in given groups and periods of the periodic table. In supporting Mbili's use of improvised materials to teach the periodic table, Moja said:

> …what you have used as those wires, that is what we have used most of the time and you know when you to come to the periods and groups, first of all the students must understand the arrangement of electrons in an atom. So the emphasis here, like in my case, before I start teaching the periodic table I must emphasize on the atomic structure. So like these first twenty elements they must use those wires and then see the arrangement of the electrons because now when you will be talking about the groups in fact they will be knowing because they will just count and see how many electrons are out there, three group three, if they are looking at the periods they just count the energy levels and they know which period this one belongs. That is more or less of what is most probable to use in teaching of periodic table.

Tatu argued, further, that when teaching the periodic table one had to bring out the trends and patterns in the properties of the elements. One has to plan for teaching and learning activities that will cover the trends and patterns in the properties of elements very well. One way of doing this is to prepare adequate periodic table charts suitable for each lesson being taught. The prepared charts ought to be prepared in a way that all students are able to view them in class. They have to be visible and readable by all students seated in class. On how to plan and implement lessons involving the periodic table, Tatu said:

> …like the periodic table, of course here what one has to bring out are the trend and the

patterns in the properties of the elements. So here then one has to bear in mind the activities that the teacher has to carry out and those the students will carry out in order to bring out these trends and patterns in their properties of the elements. So then here like you must have a chart of the periodic, one must prepare enough charts and which can be seen from far.

The in-service teachers believe that appropriate use of charts in teaching the periodic table can be reinforced through use of other teaching aids such as pointers to show the parts of the periodic table that the teacher/students were discussing or what the teacher wanted to be highlighted. By so doing, the students are able to follow the teacher's plan of action as he/she covered the periodic table. Tatu commented:

…and if the periodic tables are available, they should be appropriately hanged where they can be seen and something like a ruler or a stick must be availed to use in pointing out the elements and something like that.

Use of letters to represent the actual elements in the periodic table was found to be appropriate in allowing students to follow and understand the chemistry behind the periodic table. The use of letters helps the students to avoid cramming the properties of the individual elements in the various groups and periods of the periodic table. According to the teachers, this approach greatly assists the students in understanding the chemical concepts because they viewed the periodic table to be the core of chemistry. This approach makes the students to be able to answer any questions on the periodic table because they are able to relate the periodic table with the chemical reactions they cover in chemistry classes. In this regard, Tatu said:

For this topic of the periodic [table], I find it very appropriate in most times to use letters to stand for the elements. Of course you can provide the atomic numbers but now you use letters. Probably you use the actual names of the students in asking them let's say some questions about the elements. Once you use the actual names of the elements, then even without using the structures and any other atomic properties of the elements, the students are able to come up with the answers.

Having the teachers being more innovative in their teaching approaches and strategies can strengthen lesson plan preparation and implementation on the periodic table. Teachers can use different colors to show the patterns and families in the periodic table. The different colors are likely to assist the students when they learn various groups such as metals, non-metals, transition metals, gases, halogens, noble gases, alkalis, and alkali earth metals. Tatu said:

…Like the periodic table you see one way of really bringing out in a very colorful way, elements like you can have the metals having a different color in a chart, the non metals different color, transition elements different color or you can give the different families different colors. Alkaline

> metals different color, alkaline earth metals a different color, halogens a different color, noble gases a different color and that will enhance the understanding of the students".

Chemistry lessons on the periodic table can be improved by having a plan on how to evaluate the teaching learning sessions. As Tatu put it:

> Then, also a suitable way of evaluating the lesson must be found... So I recommend very much like when we are testing the periodic table we use letters to stand for the elements: x, y, z, a, b, c, d so they are not able to know the actual element but they are able to use the atomic properties now to come up with their properties and other things about the elements.

Lesson evaluation is an important component in teachers' lesson planning and implementation, as continuous and appropriate lesson assessments help the teachers to improve on subsequent lessons on the Periodic Table. From the discussions, it was evident that the participants believe that the Periodic Table is the core of chemistry. When handling this topic, the participants felt that a teacher has to cover first the elements' valences, secondly cover the formulae of compounds, and thirdly the chemical compounds. The participants make their periodic table lessons concrete using student activities. Students need to be thoroughly prepared in this area in order for them to understand the chemistry of various elements. This requires appropriate teaching and learning approaches in schools. Teachers ought to think about teaching/learning activities in the trends and patterns in the element properties. Teachers have to prepare charts or/and have conventional charts appropriately hanged in class. When teaching the periodic table using charts, the teacher should have a pointer to highlight the parts of the periodic table being addressed.

Findings from District Two

The in-service teachers made some changes in their chemistry unit lesson planning and implementation. The following are the findings on the teaching of the Periodic Table unit in District Two.

Lesson Planning and Implementation Following the In-service Program

Among the changes that the participants had made in District Two is the incorporation of the ASEI movement in their lesson planning and the PDSI approach in their chemistry unit lesson implementation. Saba said, "…from the SMASSE program we have learned about the PDSI approach to teaching and the ASEI lesson plans. We are currently using this approach and the ASEI lesson plan in our teaching. So the approach has improved." Previously, the participants were not evaluating their lessons with an aim of improving on the implementation of the subsequent lessons. Following the in-service courses, the teachers had changed their teaching to incorporate prior planning on lesson evaluations. Saba commented:

> For one, previously we never used to assess our lesson with intention of improving the next lesson, but now we do that. In our lessons now, we have to plan for it look for the materials required and not that particular moment during the lesson that we are running up and down to

arrange this and that but we put them ready in advance.

The in-service teachers make changes on the learning activities they use. The lesson activities are learner-centered. Sita had a teaching metaphor on how to involve students in chemistry learning. As Sita said:

> …let me have this one as "let the child do", that should be heading, the PDSI approach is actually sort of "let the child do as the teacher sees" unlike previous times when we were carrying out experiments by ourselves demonstrating. This time we have the child or the pupil involved.

Sita believes that as students participate in various learning activities, the teachers should "let the child do as the teacher sees". This is a great change from the teachers' demonstration classes they mostly used to have whenever they conducted experiments in class. Student-centered lessons are teacher friendly and the in-service teachers are able to teach any part of the chemistry curriculum using locally available materials.

Planning and Implementing Chemistry Unit Lessons Following the In-service Program

The participants gave their views on how they plan and implement their chemistry unit lessons involving the periodic table. The following examples are the participants' thoughts about their secondary school chemistry teaching on the Periodic Table.

The participants had many approaches as to how they teach the periodic table. They ensure that the students understand the atomic structure, followed by the electronic configuration of various atoms before they embark on the periodic table. Sita said:

> The periodic table actually, the approaches are many. But the real approach, which I would use here, is the students should be familiar with the structure of the atom, such that the electrons in an atom and the electronic configuration should follow.

Once the students master how to write the electronic configurations of atoms, they are introduced to grouping the atoms together based on the number of electrons they have in the outermost energy level or the number of energy levels they have being occupied by electrons. The students are then given the criteria for placing elements in the various groups or periods in the periodic table. As Sita put it:

> …they should be able to accept that the uttermost energy levels, the electrons in the outermost energy level are the ones, which are displaced. They are the ones, which can classify a given atom or a given element in a group and the fact that the number of the energy levels is the same with the period to which that element belongs.

Nane concurred with Sita that the teaching of the periodic table should start with the atomic structure. The students should be assisted to know how to write the electronic structures as a pre-requisite for understanding how the periodic table was developed. As Nane put it:

> …what [you need to start with] is actually the structure of the atom. The electronic configuration, make use of the other interactions in putting the elements in groups and also the use of the number of energy levels in giving the elements their periods. So at least in trying to talk about this periodic table, the students must be able to have that knowledge of how to write the electronic configuration and use the electronic configuration to put an element in a group and in a period.

The students are involved in various activities by drawing of charts on the periodic table. Saba said:

> …about the periodic table, the teaching learning activities involved here, for example, I involve the students using charts to try and draw the periodical table and group the elements of some similar characteristics probably the a number of electrons uttermost energy level and all that. So those are the activities students are normally involved in during the process of teaching. The resources here are things like the charts, the pencils and all that.

The use of charts in teaching the periodic table was supported by Nane who said that "actually use of charts is recommended and of course after the lesson you need to also to give some questions on the periodic table to get them to be able to even draw their own periodic table using the atomic numbers", especially for the first twenty elements in the periodic table. The students need to know more about the atomic numbers and masses. This helps students to have deeper understanding of how the elements are arranged across a periodic table or down a given group.

The use of student activities when teaching the periodic table was supported by Sita who said:

> …then, we will have a few sessions to prepare, students should be able to prepare a small chart with the first twenty elements and should be able to write their electronic configurations, properties given atomic number. The students should be informed what actual atomic number is so that they [know] what the relative atomic mass is. So that in relation to what really happens so that they know why the elements are arranged across a given period and also as within the same group why they are like that.

The participants argued that the students can be made to appreciate the trends in the reactivity series based on elements affinity for oxygen or reactions of elements with acids or water. Sita said:

> And they (students) should be able to also appreciate the fact that these elements, the reactivity series from the initial approach on the affinity for oxygen, all reactions, I should say, the reaction of metals with acids, with water. That fact alone would give them at least some close approach to the accepting about the arrangement of the elements within a given group.

On the other hand, Nane use letters that do not correspond to the elements' chemical symbols

when giving students activities to perform on the periodic table. The use of letters, other than the real chemical symbols of the elements, ensure that the students understand the concepts underlying the periodic table without cramming the properties of the elements based on their symbols. Nane said,

> the activities, of course lecturing, the students should be given a few atoms even using letters, which don't correspond to the correct symbols of those elements to write their electronic configuration once given the atomic number.

On lesson evaluation to gauge the students' understanding of the periodic table concepts, Sita felt that the students can be asked to write the electronic configurations of atoms and tell the reactions of elements and the compounds formed during such reactions. From given information, the students should also be able to predict the groups or periods of various elements. As Sita stated:

> And on the lesson evaluation, let the students find the electronic configurations, be able to tell the reactions, the various compounds formed when certain elements combine, be able to predict which group an element belongs to from the electronic configuration. I think this will give the students some good approach on this topic.

Saba commented on the importance of doing lesson assessment as the lesson progressed. He said:

> And the evaluation is normal. At the end of it all the students, are they able to, are they able to draw the charts representing the periodic table? If not, then we evaluate the lesson accordingly and then maybe help the students to know what was expected of them.

In-service teachers used lesson evaluations for diagnostic purposes. It is through such evaluations that they are able to plan for improved subsequent chemistry unit lessons. These in-service teachers' practices are likely to enhance the teaching and learning of the periodic table in secondary schools.

Conclusion

For Thai high school chemistry teachers, all concepts were considered to be difficult to very difficult (18/24 = 75%) to teach with respect to atomic structure including atomic models, subatomic particles and electron configurations. With respect to the periodic table, teaching its organization and the chemical properties of representative compounds were ranked most highly for teaching difficulty (17/24 = 71%). Of the eleven choices for most often cited problems associated with teaching chemistry, the most frequently cited items were (a) lack of concrete teaching materials including posters and models (22/24 = 92%); (b) not enough preparation time because teachers have too much extra work to do (19/24 = 80%); and (c) students do not have enough basic content and skill that are important for studying in advance (15/24 = 62%), etc. Interestingly, the second least challenging classroom issue was the number of students (5/24 = 21%). With respect to the teaching formats, Thai teachers are overwhelmingly using lecture, worksheets, assigning extra problems for completing outside of class time (homework) for both

teaching atomic structure and the periodic table. In contrast, the most frequently identified teaching formats that teachers would like to use are computer-assisted visualizations (18/24 = 75%) and using worksheets with practice problems for atomic structure (16/24 = 67%). And, for understanding the periodic table again, utilizing computer visualizations was rated highest (19/24 = 80%) as well as doing laboratory work (16/24 = 67%).

Among Kenyan high school chemistry teachers, they believe the periodic table is the core of understanding chemistry. When teaching this topic, the teachers feel that one has to first teach atomic structure with the elements' valences, secondly, introduce the formulae of compounds, and thirdly, introduce the nature of chemical compounds. Following professional development workshops, the teachers try to make their periodic table lessons concrete using student activities. The teachers focus on developing learning activities that demonstrate trends and patterns in the properties of elements. Teachers have to prepare their own charts and/or have conventional charts appropriately hung in class. Teachers need to plan for lesson evaluations in advance as they prepare to teach the periodic table. Continuous feedback during lesson implementation helps the teacher to know his or her students level of understanding and which students need more attention in specific areas. The teachers find it appropriate to use letters to represent elements when teaching the periodic table. They feel that use of letters to represent elements allows students to comprehend the chemistry behind the periodic table rather than cramming the elements' chemical facts. The teachers use question-answer techniques, rather than lecture, during instruction. They also use different colors for different family patterns/elements, for example, metals/non metals, transition elements, alkali, alkaline earth metals, and halogens. The teachers emphasize that both conventional and improvised models lead to better understanding by the students.

Discussion and Recommendations

From the Kenyan participants' conversations and observed lessons, it is evident that they taught the periodic table by considering student activities on the atomic structure, electronic configurations, reactivity of elements (involving oxygen, acids and water), and drawing charts on the periodic table for the first twenty elements. The participants discussed the periodic table using letters to represent elements, which were not their true chemical symbols. Lesson evaluations are also conducted to assess their students' grasp of the concepts about the periodic table. The lesson evaluations ensure that the students are achieving the lesson objectives in relation the teachers' expectations. In contrast, Thai chemistry teachers are looking towards innovative visual technologies to enhance teaching and students' understanding.

These results suggest that teacher practices can be enhanced through effective in-service teacher education programs. Professional development programs that effectively involve all the stakeholders and in-service teachers in decision making tend to promote acceptable science classroom practices. The in-service teachers are able to identify themselves with the changes required to enhance the teaching and learning of chemistry unit lessons such as in the periodic table. Use of appropriate assessment tools

for diagnostic purposes in science classes is promoted through teacher interactions in professional development sessions. Our findings also suggest that student-centered hands-on and minds-on activities are likely to enhance effective teaching and learning of the periodic table in secondary schools. The in-service teachers involved their students in activities such as concept word mapping, word burrs, directed activity related to science texts, and projects.

In non-western, less industrialized countries such as Kenya, the use of locally available materials in teaching and learning the periodic table was found to be appropriate in rural schools with limited science facilities. The teachers use different colors to show the different patterns, trends, and chemical families on the periodic table.

As a foundation to learning advanced chemistry content, atomic structure is one of the most important chemical concepts that learners ought to understand well. We have found that Thai and Kenyan chemistry high school teachers share the importance and difficulty in teaching these topics. The idea of fundamental particles of an atom is abstract and yet the students' understanding of the atomic structure is crucial to learning the periodic table. Through atomic structure, learners are introduced to the elements' groups and periods from which they are able to construct patterns and trends in the periodic table. The chemical and physical properties of elements grouped together or in the same period of the periodic table become clear to the learners when appropriate teaching learning strategies are employed in teaching the atomic structure. The learners' early understanding of the chemistry involved in building the periodic table makes it easier for them to learn further chemistry content. Understanding atomic structure and the periodic table assists students to comprehend chemical formulae of compounds and balancing chemical equations. Many chemistry students are likely to find chemical concepts, especially the "mole concept" difficult to study if they have a weak foundation in atomic structure and the periodic table.

In this paper, we have focused on chemistry teachers' reflections using surveys with questionnaires and interviews to learn about the difficulties they encounter in teaching basic concepts related to atomic structure and the periodic table in chemistry. We do not believe that teachers in Thailand and Kenya are different from those in the global community, but little data exists to support this claim especially with regard to rural areas. Furthermore, we do not know if the priorities of the teachers are congruent with national curricula or standards. We have identified a few prioritized issues. Our data is being used to design and create curriculum materials relevant to the teachers' and students' need and we are planning to investigate it usefulness this year.

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