Cambodian Student Competencies in Chemistry at Lower Secondary School Compared to regional neighbors and Japan

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This study investigates Cambodian student competencies in chemistry at lower secondary level by using the TIMSS 2011 standards. There were 3014 students in eighth grade of lower secondary schools of Cambodia participated in the research. Their results are then compared with the achievement of students from Japan, Thailand, Malaysia and Indonesia on the same TIMSS items. It is found that the achievement of Cambodian students is comparable to most of its regional neighbors, but is much lower than that of Japan and the ASEAN and international averages. The study discusses the findings and identifies key challenges for the current Cambodian context.

Key Words : Chemistry content domain, cognitive domain, lower secondary school, Cambodia, ASEAN

INTRODUCTION

Cambodia will face increasing regional competition when ASEAN integration becomes a reality in 2015. Its competitive status will depend greatly on the capacity of its human resources. Numerous reports have described the lack of relevant knowledge and skills of graduates from the Cambodian school system. Yet there is little reliable quantitative data to support these claims. Especially, there is little subject specific, comparative data that might indicate Cambodia's regional competitive status.

Science education plays an important role in the development of critical citizens in a rapidly changing technological society (Gimn & Watters, 1995(1); Watters & Gimn, 2000(2)). McGinn and Roth (1999)(3) emphasize that by well-organized science education, citizens can have a greater understanding of natural and scientific phenomena, and can develop skills to solve challenges they may encounter in daily life.

Chemistry is widely considered to be a central discipline among the sciences as it closely studies matter, energy and their interactions in the phenomena of our everyday lives. Understanding chemistry can help to explain changes in matter as well as many phenomena in nature (Mann, 2011)(4). Unfortunately, Cambodia has never participated in an international assessment such as Trends in International Mathematics and Science Study (TIMSS) or Programme for International Student Assessment (PISA) before, whereas several of her regional neighbors have (TIMSS, 2013(5); PISA, 2013(6)). Consequently, this investigation aims to describe Cambodian students’ competency in chemistry at lower secondary level through the use of internationally recognized TIMSS test items in both concept and cognitive domains, and compares them with Japan and other regional countries such as Thailand, Malaysia and Indonesia.

RESEARCH PURPOSE

Giving the above context, this research aims to explore Cambodian lower secondary school students’ competencies in chemistry by using TIMSS-2011 standard items. Here, the competencies are referring to the ability of students to understand the chemistry concept domain and scientific cognitive domain. The research raises the following investigative questions:

1. To what extent do lower secondary school students in Cambodia understand the chemistry concept domain?
2. How well do Cambodian lower secondary school students perform on the three components of the cognitive domain; knowing, reasoning and applying scientific knowledge?
3. What differences in performance are there between Cambodian students and those of the

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ASEAN countries, Japan and the international averages?

BACKGROUND

The Cambodian Context

Cambodia is one of the least developed countries in the world. It experienced civil war for several decades during the 1970s to 1990s, the most serious being from 1975 to 1979 in which numerous educational resources, both human and material, were destroyed. Since then, the education system in Cambodia has been reformed several times under the support of various educational projects from foreign countries (UNESCO, 1991(17); Clayton, 1997(18); Chantha, 2013(19)) yet the system remains in a weakened state with an undertrained and underpaid workforce, inadequate curriculum and wide-spread cheating on high-stakes exams that demotivates students for learning.

In the current educational system in Cambodia, Chemistry is introduced in grade 7 of lower secondary school together with other science discipline such as Physics, Biology and Earth Science. They are presented as separate sections of the same book and not as integrated science. The textbook is the only curriculum document provided by the Ministry of Education Youth and Sport (MoEYS) and there is a shortage of other teaching materials, so it is virtually the only teaching resource available for teachers. At this level, chemistry is only taught for 1 to 2 periods per week throughout grades 7 to 9 shared with other science subjects (MoEYS, 2004)(20).

Although several attempts have been made to reform the education system in Cambodia, several researchers have shown that science education in Cambodian is still in much need of improvement. According to Maeda, Pen, Set, Kita & Sieng (2006)(21), the quality of science education in Cambodia is facing three key issues: (1) shortage of appropriate educational content since most is too abstract, has little practical work, many theoretical concepts and few links to everyday application, (2) insufficient teaching and learning materials that encourages teachers to teach students mostly by rote lecturing following what is written in the textbook without providing students with real scientific observation and, (3) lack of qualified, trained teachers. The research shows that many teachers have had little or no experience in science practical work, as they have never been trained in the pre-service teacher-training program at teacher training centers. A baseline survey conducted by the Japanese, Cambodian Science Teacher Education Project, (STEPSAM2), also reported that science trainers from teacher training centers for primary and lower secondary school as well as their trainees, who become lower secondary teachers, demonstrated poor scientific knowledge and weak scientific thinking or few science process skills (STEPSAM2, 2009)(22). Recent research by Walle, Uon, Cnudde and Keo (2010)(23) and Chantha, (2013)(24) has shown similar results.

The Structure of the school system in Cambodia is the same as that in Japan, Thailand and Indonesia; 6 years of primary education, followed by 3 years of lower secondary education and 3 years of upper secondary education. Malaysia is slightly different since its primary school students start school at 7 years of age and study for 6 years, followed by 3 years of lower secondary education and 2 years of upper secondary education. However, before entering the university, Malaysian students need to study for another year called pre-university.

The Nature of Chemistry

Many researchers have found that chemistry is one of the most difficult subjects for students because it includes a number of abstract concepts that are difficult to understand (Gabel and Bunce, 1994(25); Griffiths, 1994(26); Bucat and Fensham, 1995(27); Garnett, and Hackling, 1995(28); Hans, Annette and Allan, 2007(29); Rahayu and Kita, 2010(30)). According to Johnstone (2000)(31), the difficulties may be related to human learning as well as the nature of the subject itself.

The subject of chemistry comprises different kinds of concepts compared to others. Johnstone (1982(32), 1991(33), & 2000(34)) describes three levels of chemistry concepts for learners: the macro and tangible, the submicro atomic and molecular, and the representational use of symbols and mathematics. In the case of the macro level, it is possible to have direct concept formation, as in the case, for instance, of recognizing metals and non-metals, acids and bases, flammable substances, etc. In the case, however, of concepts like elements or compounds, molecules, atoms, or electrons,
bonding types, these involve the submicro level and are very difficult concepts for students. Furthermore, to interpret and express the phenomenon of chemical change, scientific symbols and mathematics are used. Therefore, learners need to gradually build up their basic knowledge of these three main component concepts in order to able to understand chemistry.

**TIMSS**

TIMSS is an internationally comparative assessment dedicated to improving teaching and learning in mathematics and science for students around the world. By carrying out evaluations every four years since 1995 at the fourth and eighth grades, TIMSS provides data about trends in mathematics and science achievement of students around the world over time. To inform educational policy in the participating countries, this world-wide assessment and research project also routinely collect extensive background information that addresses concerns about the quantity, quality and content of instruction. In 2011, there are nationally representative samples of students from 63 countries and 14 benchmarking entities (regional jurisdictions of countries, such as states) participated in TIMSS. Two dimensions have been developed by TIMSS science assessment teams; (1) a content dimension specifying the domains or subject matter to be assessed within science; and (2) a cognitive dimension specifying the domains or thinking processes expected of students as they engage with the science content. The development is based on a comprehensive framework collaborating with the participating countries. Three cognitive domains encompassing a range of cognitive processes in solving problems are designed to assess students’ understanding in science; knowing, applying and reasoning scientific knowledge. The domain of knowing scientific knowledge is the knowledge of relevant science facts, information, tools, and procedures, while applying scientific knowledge refers to the use of knowledge in real situations and problem solving. Lastly, reasoning scientific knowledge is the skill of drawing conclusions with appropriate evidence based on inductive and deductive reasoning as well as the investigation of cause and effect (TIMSS, 2013)⁵⁹.

The cognitive domain is an area of study that focuses on the processes and the qualitative results of the study as well as the ability to apply intelligence. Cognitive domain is well-known as one of Bloom’s taxonomy learning domains commonly used to describe a student’s intellectual development. According to Bandura (1989)²³, a major function of thought is to enable people to predict the occurrence of events and to create the means of exercising control over those that affect their daily life, and this requires cognitive processing. In order to do this, people must draw on their state of knowledge to generate hypotheses and apply a process to solve the problem. According to Hanus, Hamilton & Russell (2008)²⁴, there are six categories in the cognitive domain, namely knowledge, comprehension, application, analysis, synthesis and evaluation. He refers to knowledge as a cognitive continuum that begins with students’ recall and recognition of a concept, while comprehension is the ability to translate or to interpret the concept. He refers to application as the ability of students to apply the knowledge that they comprehend. Analysis and synthesis he explains as the ability of students to analyze situations involving their knowledge and to synthesize the knowledge into new organizations. Finally, students need evaluation skills to evaluate the knowledge area to judge the value of materials and methods for a given purpose.

**Methodology**

**Research Materials**

The study used only question items developed by TIMSS in 2011 for eighth grade. Among the 217 assessment items for all science areas, the author selected 18 items related to chemistry. Among the items selected, 13 were multiple-choice questions where students could select an option that would best represent a particular concept, and 5 items were constructed response questions where students could write an appropriate explanation.

As seen in Table 1, the items covered 3 topic areas in the chemistry concept domain, namely the properties of matter, classification and composition of matter and chemical change. They were also classified into 3 categories of cognitive domain; knowing, applying and reasoning scientific knowledge. Two among the 18 items were worth 2
marks, while the others were 1 mark questions; therefore the full score was 20.

The items were translated into Khmer language and checked by our colleagues several times to make sure that the translated items could be understood properly by students. Then, the translated question items were used with two classes of eighth grade students as a pilot. Students in the pilot study didn’t raise any questions related to the translated items, so it was assumed that the translated questions were suitable for use with Cambodian students.

**Sample and Data Collection**

Following the TIMSS framework, eight grade Cambodian students were asked to participate in the research at the end of their school year from June to July, 2013. They were selected randomly from 1 to 2 classes from 34 public schools across 17 provinces/cities out of 25 throughout Cambodia, in which 1 school in town (city) and 1 school in district were collected for each province. There were 3014 students (690 were female) in total who participated in the research. The participating students were given 1 hour to write answers on the TIMSS test papers in classrooms and supervised strictly and no cheating of any type was allowed.

The collected questionnaires were marked following the instruction of correction guide by TIMSS. For multiple-choice questions students were given one mark if they chose the correct answer and zero if they chose the wrong one. In the case of constructed response questions students were given one or two marks based on their use of correct key terms to express their answers.

Data from Japan, Thailand, Malaysia and Indonesia, were collected by the author from the TIMSS 2011 database, which had already been statistically adjusted and reported the students’ achievement as average percentages. These data were used directly to compare with Cambodian students’ achievement. Moreover, the ASEAN average is calculated from the average of the 4 ASEAN countries which participated in TIMSS 2011, namely Thailand, Malaysia, Indonesia and Singapore plus this Cambodia data. However, Singapore will not be raised to discuss in the comparison by country, because it is already found as a top performance in the TIMSS similar to Japan. Therefore, the discussion will compare solely between Cambodia, Thailand, Indonesia and Malaysia where the educational situations look similar.

**Data Analysis**

The students’ scores obtained on the test were analyzed quantitatively using Microsoft EXCEL to calculate the average number of students...
who gave the correct answers and SPSS (PASW Statistics 18, version 18.0.0) to run for descriptive statistics and T-test. The data collected from Cambodia, was then compared with the secondary data of Japan, Thailand, Malaysia and Indonesia collected from TIMSS 2011 results and differences in achievement between countries in terms of concept and cognitive domains were identified.

RESULTS AND DISCUSSION

The discussion of the research finding is focused on two main areas as mentioned in the research questions. First, students’ overall understanding of the chemistry concept domain is discussed, followed by general patterns for each topic area introduced in the assessment test, namely, properties of matter, classification and composition of matter, and chemical change. Second, the discussion focuses on students’ performances in the cognitive domain. Here, three student competencies are considered; the abilities of knowing, applying and reasoning scientific knowledge. For each discussion, a comparison is made between the Cambodian students’ achievement and that of Japan, Thailand, Malaysia and Indonesia as well as the ASEAN and international averages.

Students’ Understanding of the Chemistry Content Domain

Figure 1 and Table 2 show Cambodian students’ overall understanding of the chemistry concept domain in the test. It can be seen that the majority of Cambodian students performed lower than average scores. They got only 6.39 or 31.95% on average out of the total 20 score on the 18 items.

![Histogram](image)

**Figure 1. Score distribution of Cambodian students’ achievement**

<table>
<thead>
<tr>
<th>N (students)</th>
<th>3104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum scores</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Maximum scores</td>
<td>18 (90.00%)</td>
</tr>
<tr>
<td>Mean</td>
<td>6.39 (31.95%)</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>2.953</td>
</tr>
</tbody>
</table>

Table 2. Descriptive statistics of Cambodian students’ scores obtained from the test.

Although some Cambodian students achieved a maximum total score of 18 (90.00%), the minimum was 0.00%. This is a very wide distribution of scores that some Cambodian students gave completely wrong answers, while others could give correct answers to nearly all the questions in the assessment test.

The results also show that there was not a significant difference in performance between male students (N=613, M=6.34, SD=3.044) and female students (N=690, M=6.44, SD=2.873); p=0.537>0.05. On the other hand, the students from the districts (N=655, M=6.56, SD=2.971) seemed perform the test slightly better than those from the towns (N=649, M=6.28, SD=2.928); p=0.043<0.05. However, their mean scores did not show big difference. This indicates that the students have received the similar teaching and learning opportunity in Cambodian schools.

Figure 2 shows the number of students in percentage that responded the correct answer by item comparing amongst Cambodia, Japan, Thailand, Malaysia, Indonesia and the ASEAN and International averages. The results show that, with the exception of Japan, the students from participating countries performed lower on the TIMSS assessment test than the ASEAN and international averages. Less than 50% of the students from the countries involved gave the correct answers to most of the test items.

Cambodian student's achievement was comparable to those of Thailand, Malaysia and Indonesia, however, they were all still below the ASEAN and international averages.

Table 3 shows the number of Cambodian students, on average, who responded with the correct answers amongst the 18 question items in total compared to those of Japanese, Thai, Malaysian, Indonesian students, as well as the ASEAN and international averages. Overall, it can be seen that it parallels the score achievement in
Table 2. The number of Cambodian students who were able to understand the concepts of chemistry presented by the TIMSS items was only 34.42%, much below 50%, while the TIMSS 2011 result was 59.67% for Japanese students, 40.90% for the ASEAN and 47.50% for the international average. However, the results show that Cambodian students (34.42%) performed somewhat better than Indonesians (27.89%), though slightly below Thai (36.83%) and Malaysian students (36.94%). Japanese students showed the top performance among the comparison countries and were even higher than the international average.

Table 3. Average Percentage of Cambodian students that responded correct answers to the 18 items compared to regional countries, Japan, ASEAN and International.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>4.00</td>
<td>83.00</td>
<td>34.42</td>
</tr>
<tr>
<td>Thailand</td>
<td>6.00</td>
<td>93.00</td>
<td>36.83</td>
</tr>
<tr>
<td>Malaysia</td>
<td>8.00</td>
<td>84.00</td>
<td>36.94</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4.00</td>
<td>92.00</td>
<td>27.89</td>
</tr>
<tr>
<td>ASEAN</td>
<td>5.50</td>
<td>88.00</td>
<td>40.90</td>
</tr>
<tr>
<td>International</td>
<td>18.00</td>
<td>88.00</td>
<td>47.50</td>
</tr>
<tr>
<td>Japan</td>
<td>24.00</td>
<td>99.00</td>
<td>59.67</td>
</tr>
</tbody>
</table>

### a. Properties of Matter

The three items (items No.1, 6 and 13 as shown in Table 1), which were all multiple-choice questions, were designed to investigate the students’ understanding of this concept. As seen in Table 4, many Cambodian students could not respond with the correct answers on the test. Only 27.94% of the students in average, which was the smallest number amongst the comparison countries could understand the concept of properties of matter as presented by the TIMSS items. Even though this number was slightly below Indonesia (29.67%), this result was clearly below Japan, Thailand and Malaysia as well as the ASEAN and the International averages.

### b. Classification and Composition of Matter

The ten question items were designed to test
understanding of classification and composition of matter. Among those, eight items (items No. 3, 4, 8, 10, 12, 15, 16 and 17) were multiple-choice questions and two items (items No. 7 and 18) were constructed response questions. In this topic area, Cambodian students showed slightly better understanding than those of Thailand, Malaysia and Indonesia. However, the number was still below 50% and still below the Japanese, ASEAN and international averages. As seen from Table 5, 38.36% of Cambodian students gave the correct answer to the question items in this topic area while 34.40%, 31.70% and 24.60% of students for Thailand, Malaysia and Indonesia respectively. In this concept category, Japan was still at the top number and even higher than the ASEAN and international averages.

Table 5. Percentage of Cambodian students that responded correct answers to the topic area of the classification and composition of matter compared to regional countries, Japan, ASEAN and International in averages.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>8.00</td>
<td>83.00</td>
<td>38.36</td>
</tr>
<tr>
<td>Thailand</td>
<td>19.00</td>
<td>73.00</td>
<td>34.40</td>
</tr>
<tr>
<td>Malaysia</td>
<td>15.00</td>
<td>67.00</td>
<td>31.70</td>
</tr>
<tr>
<td>Indonesia</td>
<td>7.00</td>
<td>89.00</td>
<td>24.60</td>
</tr>
<tr>
<td>ASEAN</td>
<td>24.00</td>
<td>81.00</td>
<td>39.10</td>
</tr>
<tr>
<td>International</td>
<td>25.00</td>
<td>85.00</td>
<td>44.60</td>
</tr>
<tr>
<td>Japan</td>
<td>24.00</td>
<td>99.00</td>
<td>58.90</td>
</tr>
</tbody>
</table>

c. Chemical Change

Table 6. Percentage of Cambodian students that responded correct answers to the topic area of the chemical change compared to regional countries, Japan ASEAN and International in averages.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>4.00</td>
<td>70.00</td>
<td>30.43</td>
</tr>
<tr>
<td>Thailand</td>
<td>6.00</td>
<td>93.00</td>
<td>41.20</td>
</tr>
<tr>
<td>Malaysia</td>
<td>8.00</td>
<td>84.00</td>
<td>41.40</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4.00</td>
<td>92.00</td>
<td>36.20</td>
</tr>
<tr>
<td>ASEAN</td>
<td>10.00</td>
<td>87.00</td>
<td>43.40</td>
</tr>
<tr>
<td>International</td>
<td>18.00</td>
<td>88.00</td>
<td>51.80</td>
</tr>
<tr>
<td>Japan</td>
<td>26.00</td>
<td>94.00</td>
<td>62.00</td>
</tr>
</tbody>
</table>

The five questions items were designed to assess students’ understanding of the concept of chemical change. Among those questions, two were multiple-choice questions (items No. 5 and 14), while the other three were constructed response questions, which require students to write answers (items No. 2, 9 and 11). Cambodian students continued to show low achievement in the concept of chemical change. As shown in Table 6, only 30.43% of the students could understand and give correct answers in this topic area. This is again the smallest number amongst the comparison countries and was below the ASEAN (43.40%) and international averages (51.80%), while Japan was still at the top number and higher than the international average.

The summary of Cambodian students’ achievement amongst the three concept areas in the content domain compared with ASEAN and the international averages is shown in Figure 3.

Figure 3. Summary of students’ achievement in the content domain

Students’ performances in the Cognitive Domain

In general, the performance in the cognitive domain of students in all comparison countries followed the same pattern, as seen in Figure 4, and this was reflected in the ASEAN and the international averages.

The highest achievement was in knowing scientific knowledge, followed by reasoning and then applying scientific knowledge. Amongst these countries, Japanese students displayed the highest ability in all cognitive domains, and ranked even higher than the international and ASEAN averages. The achievement of other countries was in decreasing order, Malaysia, Thailand, Cambodia and Indonesia.
a. Knowing Scientific Knowledge

The seven question items on the assessment test (items No. 5, 7, 8, 9, 12 and 13) were designed to measure the extent of students' knowing scientific knowledge as shown in Table 1. Cambodian students’ knowledge in science was below the comparison countries and the ASEAN and international averages. From Table 7, Cambodian and Indonesian students have similar weaknesses in this cognitive domain as only 46.67% of Cambodian students and 46.29% of Indonesian students could respond with correct answers, while Japanese, Malaysian, and Thai students had 73.14%, 51.00%, and 49.29% respectively.

Table 7. Percentage of Cambodian student performed well in knowing scientific knowledge compared to regional countries, Japan, ASEAN and International.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>8.00</td>
<td>83.00</td>
<td>38.36</td>
</tr>
<tr>
<td>Thailand</td>
<td>19.00</td>
<td>73.00</td>
<td>34.40</td>
</tr>
<tr>
<td>Malaysia</td>
<td>15.00</td>
<td>67.00</td>
<td>31.70</td>
</tr>
<tr>
<td>Indonesia</td>
<td>7.00</td>
<td>89.00</td>
<td>24.60</td>
</tr>
<tr>
<td>ASEAN</td>
<td>24.00</td>
<td>81.00</td>
<td>39.10</td>
</tr>
<tr>
<td>International</td>
<td>25.00</td>
<td>85.00</td>
<td>44.60</td>
</tr>
<tr>
<td>Japan</td>
<td>24.00</td>
<td>99.00</td>
<td>58.90</td>
</tr>
</tbody>
</table>

b. Reasoning Scientific Knowledge

Four question items (item No. 1, 4, 6 and 18) were included in the test to understand the students' skills in reasoning scientific knowledge. One of the items was a constructed response question (item No. 18). As seen in Table 8, only 25.19% of Cambodian students could give appropriate reasons for the scientific concepts presented in the test. Although this was slightly higher than the Indonesia, it was lower than other regional countries, Thailand and Malaysia as well as the ASEAN average. Compared to Japan and the international average, Cambodia was even further behind.

c. Applying Scientific Knowledge

Seven question items were presented to assess the skills of applying scientific knowledge (items No. 2, 3, 10, 11, 15, 16 and 17), in which two (items No. 2 and 11) were constructed response questions, as seen in Table 1. In this skill domain, Cambodian students' performance was similar to regional comparison countries. They performed slightly better than Indonesian and Malaysian students, but were slightly below Thai students as seen in Table 9. However, this result was again below the ASEAN and international averages and Japan.

Table 9. Percentage of Cambodian student performed well in applying scientific knowledge compared to regional countries, Japan, ASEAN and International.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Minimum (%)</th>
<th>Maximum (%)</th>
<th>Mean (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>4.00</td>
<td>71.00</td>
<td>27.46</td>
</tr>
<tr>
<td>Thailand</td>
<td>6.00</td>
<td>59.00</td>
<td>28.86</td>
</tr>
<tr>
<td>Malaysia</td>
<td>8.00</td>
<td>43.00</td>
<td>25.71</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4.00</td>
<td>25.00</td>
<td>19.00</td>
</tr>
<tr>
<td>ASEAN</td>
<td>10.00</td>
<td>52.00</td>
<td>31.43</td>
</tr>
<tr>
<td>International</td>
<td>18.00</td>
<td>58.00</td>
<td>37.57</td>
</tr>
<tr>
<td>Japan</td>
<td>24.00</td>
<td>73.00</td>
<td>44.57</td>
</tr>
</tbody>
</table>

IMPLICATIONS FOR CAMBODIA

In general, Cambodian student showed similar performance in chemistry competency amongst males and females as well as towns and
districts. However, their achievement was low compared to that of the regional comparison countries on the TIMSS assessment items. Only Indonesia was lower in both concept and cognitive domains. Cambodian students were significantly below the ASEAN and the international average in both content and cognitive domains.

The following is a discussion of the implications of the research results for the current Cambodian science education context. The discussion focuses on the greatest weaknesses of Cambodian student achievement in each domain in order to magnify the problems in the current Cambodian education context.

The Content domain

As shown in the research results in the content domain, Cambodian students achieved an overall third position amongst the four regional comparison countries, behind those of Malaysia and Thailand, and above Indonesia. Cambodian students achieved below the ASEAN and international averages and significantly behind those of Japan. In the specific content areas, Cambodian students showed better than average achievement in the Classification and Composition of Matter, scoring higher than all its regional neighbors (Figure 3), but still lower than the ASEAN and international averages and Japan. However, Cambodian students scored lowest in the region in the areas of Properties of Matter and Chemical Change.

For instance, in the concept area of the properties of matter, only a few Cambodian students could respond with the correct answers to the assigned items (No. 1, 6 and 13), as shown in Figure 2. Question item No.1 assesses the students’ understanding of the change in solubility of sugar with temperature by asking them to choose an appropriate solubility graph. Only 15% of students who participated in the test could explain that the dissolved amount of sugar in water increased when the temperature increased. In the case of question item No. 6, which requires students to select the property of water that has the most effect on splitting a rock into two pieces, only 12% of them could choose the correct statement, “water expanding when it freezes.” Question item No. 13 asks the students to choose the correct term used to describe the process that occurs when ammonia solution is added to a red colored solution of vinegar until the color disappears. The 57% of Cambodian students could choose the right answer explaining that this process is called “neutralization”, and this result is similar to the students from regional countries like Thailand, Malaysia and Indonesia.

It should be noted that the concept of properties of matter exists in the current Cambodian lower secondary school curriculum from 7th grade throughout to 8th grade (Cambodian Textbook 7th grade, 2011[27], 8th grade, 2013[28]). But the concept of solubility of matter in water is described very briefly, only as a definition in Grade 8, and the change in solubility is never shown graphically. Therefore, the students may have had difficulty understanding the meaning of the scientific data expressed in the graph. Similarly, the properties of water are also discussed in both the 7th and 8th Grade textbooks. However, the content focuses on the changes of water between solid, liquid and gas states, the water cycle and water composition, while the concept of the volume of water expanding when it becomes solid (ice) is not discussed. Therefore, the power of water to break a stone into small pieces by volume expansion when it freezes, as described in the test, is not a familiar one with Cambodian students. Moreover, the concept of acid-base is not introduced in 7th nor 8th grades, but in the 9th grade (Cambodian Textbook 9th grade, 2012) [27] and the changes in color of acid-base indicators, as described in the test item, is not discussed until the upper secondary level in 11th grade. Therefore, it might be difficult for Cambodian students to understand these concepts.

While Cambodian student achievement was relatively better than regional comparison countries in the concept area of the classification and composition of matter, they had lower performance in the concept area of chemical change. Less than 10% of the students answered correctly to the three question items among the five in the area of chemical change. The three questions are items, No. 2, 9 and 11, as seen in Figure 2, are constructed response questions. The question item No. 2 requires students to write an explanation of the reason why a balloon inflates when sodium bicarbonate is mixed with vinegar. Only 10% of the students could write an appropriate explanation by
using correct terms such as “the balloon inflates because of the carbon dioxide gas or gas is released from the reaction between the sodium bicarbonate and the vinegar.” In the case of questions No. 9 and 11, only 4% Cambodian students could give correct answers to each. This is a very low performance. The question item No. 2 asks students to describe two pieces of evidence that could be observed when a chemical reaction is taking place, while question No. 11 asks students to give evidence to show that energy is released during a chemical reaction.

The content covered in these test items is more practical and not simply recall of knowledge. Looking at the content in the Cambodian textbooks, the concept of chemical change is introduced from 7th grade through 8th grade. However, only a few chemical reactions are discussed theoretically and abstractly, such as burning a candle or charcoal, combustion of some metals like copper and magnesium, reaction of iron powder and sulfur powder, and the reaction of hydrogen with oxygen. The discussion also has little linkage with daily life and materials. There is neither the reaction of vinegar with carbonate, nor any discussion of the release or absorption of heat from the reaction. Moreover, Cambodian students have little or no opportunity to observe chemical change phenomena in the classroom as already mentioned from a previous survey in the introduction and background of this paper. Therefore, the question items in this concept area are again beyond the Cambodian students’ capacity and are not familiar to them. This may help to explain their low achievement in this conceptual area.

Following the above discussion, it can be seen that the chemistry content in the current Cambodian curriculum and textbooks does not meet an international assessment level, as assessed by TIMSS, especially the topic area of properties of matter and chemical change. Much of the content assumed in TIMSS does not exist in the Cambodian textbooks at this level. This finding is in accordance with previous research which has reported that the current Cambodian science curriculum and textbooks are lacking in content and links with familiar materials and real phenomena in daily life, and also that the content which is present is too theoretical and abstract (Morimoto, & Maeda, 2002 (24); Maeda, Pen, Set, Kita & Sieng, 2006(11); Sieng, Atsushi & Takeshi, 2006(25); Buccella, Ozturk&Pritt, 2013(10); Thlang, 2013(31) and NIE, 2013(32)).

Therefore, the current Cambodian curriculum and textbooks for science should be reviewed and revised to enrich content to meet regional and international standards.

The cognitive domain

As seen in Figure 4, Cambodian students have lower performance in the cognitive domain than regional countries Thailand and Malaysia, though slightly higher than Indonesian students. The largest differences in cognitive skills between Cambodian students and their regional counterparts were in applying and reasoning scientific knowledge. This result is significant because these two skills are very important to develop students’ scientific process skills. Harlen (1999)(33) and Karsli&Sahin (2009)(34) suggest that both students and educators need science process skill to understand and interpret the natural phenomena surrounding them, because scientific processes are inseparable from the conceptual understanding involved in learning and applying scientific knowledge. However, these skills appear to be relatively low in the current generation of Cambodian students.

The question items assigned to assess the students’ competencies in the areas of applying and reasoning scientific knowledge are not only based on knowledge, but more on practice. Students who have been exposed to practical work in science are more likely to be able to answer correctly on this kind of test items. For instance, question item No. 1 asks students to choose the most reasonable graph to express the change in solubility of sugar in water with temperature; No. 2 asks students to write an explanation giving the reason why a balloon inflates; Item No. 11 asks students to describe evidence that could be observed when a chemical reaction releases heat; Item No. 16 asks students to apply the concepts of element, compound and mixture to everyday materials such as air, salt, sugar, gold, sea water and helium; and item No. 18 asks students to write an appropriate sentence to tell how to identify matter as a metal.

Students would have difficulty answering such questions unless they were familiar with
scientific observations through real experiment or
demonstration in the science classroom, which is
rare in Cambodia. It is therefore not so surprising
that on average only 25.29% and 27.46% of
Cambodian students respectively, demonstrated
adequate skills of reasoning and applying scientific
knowledge, as seen in Table 8 and 9. Although the
differences between regional countries seem small
in this domain, they are still significantly below the
ASEAN and International averages as well as Japan.

These results clearly imply that the current
science education in Cambodia does not promote
enough the students’ scientific skills in the
classroom. They might be influenced by several
factors in the current Cambodian context as
reviewed by the previous researches, such as lack of
appropriate teaching content, teaching and learning
materials and science teacher competency.

Following these findings, it can be
recommended that science education in Cambodia
should pay increased attention to the reform of
science content and ways of teaching together with
available teaching materials in order to encourage
and provide students with enough opportunities to
explore scientific practical work. Therefore, the
students can develop their skills in analysis and
interpretation of unfamiliar problems or
phenomena by using their knowledge to provide a
scientific explanation. Murphy & McCormick
(1997)(33) suggest that practice is the key to
developing good problem solving skills which can
sharpen many scientific skills at the same time, such
as the skills of observation, questioning, data
collection, data analysis, data interpretation,
reasoning, drawing conclusions and so on. Besides
real practice in science lessons like experiments or
demonstrations, several effective teaching methods
and materials can also be used to help students to
visualize abstract theory. For example Huddle,
White, and Rogers (2000)(34) suggested the use of
teaching models to draw students from scientific
misconception in South Africa, and Sanger and
Greenbowe (2000)(35) suggested the use of computer
animations depicting chemical reactions at the
molecular level to construct students’ visual
understanding of chemistry.

Although this research is focused on only a
single subject, chemistry is a central science and
encompasses the basics of reasoning and applying
knowledge; the higher order cognitive skills that are
considered necessary in a modern knowledge based
economy. Cambodia will soon need to compete on
an almost even playing field with its regional
neighbors in 2015 after ASEAN integration so its
relative position will become increasingly
important. The results of this research suggest that
Cambodia is significantly below most of its regional
neighbors in these basic thinking skills and so will
need to focus on reform of science education in
order to compete.

"Science is a way of thinking much more
than it is a body of knowledge"
(Carl Sagan, 2014)(33).

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