# The science education of the East Asian regions – what we can learn from PISA

**Kwok Chi LAU**

**Chinese University of Hong Kong, HONG KONG**

**E-mail: lau.kwokchi@gmail.com**

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## Abstract

The study has integrated the data from PISA 2006 to 2012 to give an overall picture of the cognitive and affective performances and pedagogy of East Asian regions on PISA scientific literacy. Attempts are made to account for their performances based on the PISA data and cultural characteristics. The cognitive science performance of East Asian regions is definitely very good. On the affective measures, East Asian students tend to have low self concept on learning science, but they generally show high interest in and give high value toward science and science learning except for many students in Japan and Korea. Science teachers in these regions tend to teach more traditionally: fewer hands on activities, less interaction and less emphasis on the application of science. HLM analysis reveal that interaction, hands on activity and investigation seem not much related to good cognitive and affective performances for most East Asian regions, particularly for Japan and Korea. Despite large class sizes, East Asian students are attentive and disciplined in class. Teachers, though demanding and authoritarian in class, get along well with students and are eager to offer help on their learning after class. Despite ordinary class time for learning science, students in East Asian schools often spend lots of time on after-school tutorial classes, which, together with less truancy and greater attentiveness in class, render the actual learning time of East Asian students more. The Confucian culture and the related characteristics of the Chinese learners and teachers are probably the root causes to the performances and characteristics of these East Asian regions.

# Introduction

East Asian regions (all the countries and economies are called regions in this article) have consistently ranked top in international assessments of science, particularly in the Programme for International Student Assessment (PISA). In PISA 2012, among the top ten regions in science performance, six come from East Asia (culturally defined), including Hong Kong, Shanghai, Singapore, Japan, Korea and Vietnam. Hong Kong has never been ranked below 3rd since 2000, and Shanghai ranked 1st in two consecutive assessments since she first joined PISA in 2009.

The remarkable PISA performance of the East Asian regions have gradually created puzzles about what counts as 'good' science education in particular, and 'good' education in general. The western countries are interested in finding out what makes the East Asian students outperform their students given the common notion that the East Asian learners generally learn by rote and teachers are authoritarian and traditional, using expository and didactic pedagogy. More puzzling is that PISA does not purport to assess only memorization of facts but application of concepts in novo contexts, problem solving abilities, and understandings of scientific process and nature of scientific knowledge. These learning outcomes hardly come as a result of rote learning and diligence. This has created the so called "paradox of the Chinese learner" and the "paradox of the Chinese teacher" (Chan & Rao, 2009; Watkins & Biggs, 2001).

This study aims to shed light on these paradoxes through looking more closely into the performances and other features of the science education of the East Asian regions through the lens of PISA. The analysis will base on the data from all cycles of PISA assessments, particularly those from PISA 2006 wherein science was the major domain and much more information regarding the science pedagogy and attitudes of students are available. Since only five East Asian regions took part in PISA 2006: Hong Kong, Taipei, Japan, Korea and Macau, while Shanghai, Singapore and Vietnam joined the assessment later, some of the analyses can only be made on the five regions having data in 2006. Though the data in PISA 2006 seem a little outdated, this study is deemed timely since the 2015 PISA is coming with science as the major domain again, and a comprehensive review of the top East Asian regions in the past ten years would give directions to more in-depth study using the 2015 data.

The specific questions this study aims to answer are:

1. What are the performances, both cognitive and affective, of the East Asian regions in the PISA assessment of scientific literacy?
2. What are the characteristics in science pedagogy of these East Asian as revealed by the PISA data?
3. How are the science performances connected with pedagogy and other school factors in these East Asian regions?

## Scientific literacy as assessed in PISA

In PISA 2006, scientific literacy is defined as an individual's:

- scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- understanding of the characteristic features of science as a form of human knowledge and enquiry
- awareness of how science and technology shape our material, intellectual and cultural environments

- willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen

According to the above definition, scientific literacy is assessed in two domains of knowledge: knowledge of science (knowledge about the natural world) and knowledge about science (knowledge about science itself), and three kinds of scientific competency: identifying scientific issues, explaining phenomena scientifically, and using scientific evidence. The domains of knowledge and the competencies are related; each competency draws on either students' knowledge of science or knowledge about science, or both.

## Cognitive Performance of East Asian regions in scientific literacy

Five East Asian regions, Hong Kong, Japan, Korea, Taipei and Macao, participated in PISA assessment since 2006 where science was the major domain, whereas Shanghai, Singapore and Vietnam joined the test in 2009 and 2012. Among these East Asian regions, Hong Kong, Japan, Korea, Shanghai, Singapore have consistently ranked top in scientific literacy in two or more cycles of assessment (Table 1). Particularly noteworthy is Shanghai - it stands firmly at the top with nearly 30 points higher than the second region since she first took the assessment in 2009. Vietnam took part in 2012 for the first time and was ranked eighth. Macao and Taipei, though not as top as other East Asian regions, were still among the good performers in PISA. On the whole, the PISA science performance of the East Asian regions as a group is extraordinarily good among the 67 countries/economies, which even holds true when compared with the western OECD countries - all have their scores above the OECD averages. More importantly, many of these East Asian regions: Hong Kong, Macao, Singapore, Korea, have been steadily improving in their scores over successive assessment cycles.

**Table 1.** Rank and scaled score of scientific literacy of the East Asian regions in all the PISA assessments.

| | **Rank (scaled scores*)** | | | | |
|---|---|---|---|---|---|
| **Country/Region** | **PISA 2012** | **PISA 2009** | **PISA 2006** | **PISA 2003** | **PISA 2000+** |
| Shanghai-China | 1 (580) | 1 (575) | - | - | - |
| Hong Kong | 2 (555) | 3 (549) | 2 (542) | 3 (539) | 3 (541) |
| Singapore | 3 (551) | 4 (542) | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Japan | 4 (547) | 5 (539) | 6 (531) | 2 (548) | 2 (550) |
| Korea | 7 (538) | 6 (538) | 11 (522) | 4 (538) | 1 (552) |
| Vietnam | 8 (528) | - | - | - | - |
| Chinese Taipei | 13 (523) | 12 (520) | 4 (532) | - | - |
| Macao-China | 17 (521) | 18 (511) | 17 (511) | 7 (525) | - |

* The OECD average of the scaled score is set to be 500.

The East Asian regions not only have high average scores, but also high proportion of top performers - Shanghai, Singapore, Japan and Hong Kong have more than twice the top performers (at levels 5 & 6) of the OECD average (Table 2). Their proportions of students who have not attained basic scientific literacy (below level 2) are also substantially lower than the OECD average.

**Table 2.** Proportions of low and top performers in scientific literacy of the East Asian regions in PISA 2012

| **Regions** | **Students at levels 5 and 6 (%)** | **Students below level 2 (%)** |
|---|---|---|
| Shanghai-China | 27.2 | 2.7 |
| Singapore | 22.7 | 9.6 |
| Japan | 18.2 | 8.5 |
| Hong Kong | 16.7 | 5.6 |
| Korea | 11.7 | 6.6 |
| Vietnam | 8.1 | 6.7 |
| Chinese Taipei | 8.3 | 9.8 |
| Macao-China | 6.7 | 8.8 |
| **OECD average** | **8.3** | **17.8** |

Regarding the performances in different knowledge domains, it was found that these East Asian regions are not different from other OECD countries (Table 3). Some attribute the good performance of East Asian students to memorization of science contents, but this notion is not supported by the data. The East Asian students outperformed their OECD counterparts on knowledge about science, identifying scientific issues and using scientific evidence, which all call for understandings of scientific inquiry and nature of science rather than science contents. Moreover, with regard to the relative performance in the three competencies, the scores in explaining phenomena scientifically, a competency calling for understanding of science contents, are similar to or even lower than the other two competencies in most regions except Vietnam.

**Table 3.** The performance of the East Asian regions on different domains of knowledge in PISA 2012

| | **% correct of the items in the domain** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Shanghai | HK | Taipei | Macao | Singapore | Japan | Korea | Vietnam | **OCED average** |
| | 580 | 555 | 523 | 521 | 551 | 547 | 538 | 528 | |
| **Knowledge of science** | | | | | | | | | |
| Earth and space systems | 66.9 | 61.9 | 61.0 | 56.9 | 58.0 | 66.7 | 64.7 | 59.6 | **55.8** |
| Living systems | 60.0 | 59.9 | 52.1 | 51.4 | 55.7 | 52.2 | 49.6 | 59.5 | **46.4** |
| Physical systems | 77.6 | 69.5 | 64.0 | 63.3 | 67.7 | 68.2 | 64.4 | 66.1 | **60.2** |
| Technology systems | 80.2 | 73.2 | 73.7 | 66.8 | 70.6 | 73.5 | 74.2 | 72.2 | **63.7** |
| **Knowledge about science** | | | | | | | | | |
| Scientific enquiry | 69.2 | 64.2 | 53.9 | 55.6 | 61.8 | 59.9 | 58.7 | 56.3 | **53.1** |
| Scientific explanation | 70.1 | 65.6 | 57.5 | 58.7 | 66.7 | 64.6 | 62.9 | 55.1 | **53.3** |
| **Competency** | | | | | | | | | |
| Explaining phenomena scientifically | 67.0 | 63.2 | 58.2 | 56.4 | 59.7 | 61.2 | 58.4 | 61.3 | **53.1** |
| Identifying scientific issues | 70.4 | 66.7 | 56.2 | 58.1 | 62.6 | 62.3 | 61.4 | 57.4 | **54.9** |
| Using scientific evidence | 71.4 | 65.4 | 59.3 | 58.5 | 66.7 | 64.5 | 63.3 | 58.2 | **54.3** |

Despite the common belief that East Asian regions are patriarchal and boys are likely favored in education, there found no significant differences in the science performances between boys and girls for most East Asian regions except Japan (OECD, 2014a).

# Attitudes toward science and science learning

In PISA 2006 where science was the major domain, various attitudinal constructs about science and science learning were assessed using Likert scale items (Table 4). Some sample items for each construct are shown in Table 5 .

As compared to the OECD students, students from the three Chinese regions: Hong Kong, Taipei and Macao, tended to have greater interest in science and enjoyment of science learning, and valued more science learning from both personal and future career perspectives (Table 4). However, despite their good performance and high interest, they had low self-concept in science. Students in Japan and Korea, different form their Chinese counterparts, were below the OECD averages in almost all attitudinal constructs.

Interest and enjoyment pertain more to intrinsic motivation (Krapp, 1999), while instrumental and career oriented motivations are more related to extrinsic motivation when it refers to learning as a voluntary action. The data show that Chinese students were both intrinsically and extrinsically motivated, whereas Japanese and Korean students seemed relying more on extrinsic motivation for their science learning. One thing common to all East Asian regions was low self concept (relative to the OECD average). Asian teachers are "extraordinarily mean in their marking, a deliberate strategy for extracting ever more efforts from students" (Watkins & Biggs, 2001, p.16), which in turn undermines the confidence of students in their abilities in coping with tests. However, their efforts toward learning were probably not weakened accordingly due to the Confucian heritage in these East Asian communities, which emphasizes effort over ability, study as a kind of hardship, and failure as necessary for future success.

**Table 4.** Attitudinal indexes of five East Asian regions in PISA 2006

| | General interest in science | Enjoyment of learning science | General value of science | Self concept in science | Self efficacy in science | Instrumental motivation to learn science | Future oriented motivation to learn science |
|---|---|---|---|---|---|---|---|
| **Hong Kong** | 0.19 | 0.38 | 0.55 | -0.25 | 0.06 | 0.16 | 0.29 |
| **Taipei** | 0.09 | 0.17 | 0.72 | -0.4 | 0.18 | 0.27 | 0.14 |
| **Macau** | 0.1 | 0.41 | 0.54 | -0.11 | -0.11 | 0.39 | 0.17 |
| **Japan** | -0.13 | -0.26 | -0.18 | -0.87 | -0.53 | -0.43 | -0.24 |
| **Korea** | -0.24 | -0.17 | 0.27 | -0.71 | -0.21 | -0.26 | -0.25 |

The value is scaled by setting the OECD average to be zero and a standard deviation of -1 to +1

**Table 5.** Attitudinal constructs and sample items in PISA 2006

| Attitudinal construct | Sample questions |
|---|---|
| General interest in science | The interest in the following subjects: e.g. human biology, ways scientists design experiments |
| Enjoyment of learning science | I enjoy acquiring new knowledge science |
| General value of science | Science is important for helping us to understand the natural world |
| Self concept in science | School science topics are easy to me |
| Self efficacy in science | How easy do you think you can perform the following tasks: e.g. Describe the role of antibiotics in the treatment of diseases. |
| Instrumental motivation to learn science | I study school science because I know it is useful to me. |
| Future oriented motivation to learn science | I would like to work in a career involving science. I would like to study science after secondary school. |

# Pedagogy

In PISA 2006, students were asked to indicate the time they spent in four kinds of science-related pedagogy in class: application of concepts, interaction between students and teacher, hands on activities and investigations (Table 6). Investigations are different from hands on activities in that investigation refers to those students are given the autonomy to decide on the question and design of the experiment.

**Table 6.** Sample items for the four constructs of science pedagogy in PISA 2006

| Pedagogy | Sample of items |
|---|---|
| | When learning school science topics at school, how often do the following activities occur? (*In all lessons/In most lessons/In some lessons/Never or hardly ever*) |
| Application | The teacher explains how a <school science> idea can be applied to a number of different phenomena |
| Interaction | Students are given opportunities to explain their ideas |

| | |
|---|---|
| Hands on activities | Students spend time in the laboratory doing practical experiment |
| Investigation | Students are allowed to design their own experiments |

As shown in Table 7, the values of most of the pedagogy indices were negative, revealing that the use of these pedagogies in the East Asian classroom was less than that of the OECD countries on average. The teaching in Japan and Korea was more traditional than the Chinese communities- less application focused, least interactive, and few hands on and investigative activities. The traditional pedagogy, however, seemed not having very negative impacts on the cognitive performance of these regions.

**Table 7.** The indices of the four pedagogies in PISA 2006

| **Regions** | **Application** | **Interaction** | **Hands on activity** | **Investigation** |
|---|---|---|---|---|
| **Hong Kong** | -0.003 | -0.291 | 0.288 | 0.215 |
| **Taipei** | 0.13 | -0.061 | -0.101 | 0.09 |
| **Macau** | -0.185 | -0.41 | -0.191 | 0.023 |
| **Japan** | -0.931 | -1.14 | -0.519 | -0.241 |
| **Korea** | -0.335 | -1.039 | -0.419 | -0.205 |

The value is scaled by setting the OECD average to be zero and a standard deviation of -1 to +1

# Relations of Pedagogy, cognitive performance and attitudes

To understand how pedagogy in science impact learning, Lau, Ho and Lam (in press) used hierarchical linear modeling (HLM) to explore the associations of the four kinds of pedagogy with student performance and attitudes at both student and school levels. The school level variables include the socioeconomic and academic status of the students of a school, and the school pedagogies. The results at student levels are shown in Table 8.

**Table 8.** HLM analysis of the student level associations of pedagogies with overall scores, self-concept and enjoyment of science learning of the five East Asian regions in PISA 2006

| | Application | | | Interaction | | | Hands on activity | | | Investigation | | | Science activity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Overall score | Self-concept in science | Enjoyment of science learning | Overall score | Self-concept in science | Enjoyment of science learning | Overall score | Self-concept in science | Enjoyment of science learning | Overall score | Self-concept in science | Enjoyment of science learning | Overall score | Self-concept in science | Enjoyment of science learning |
| **HK** | 17.39*** | .170*** | .172*** | -5.47* | .097** | 0.042 | 4.76* | .053* | 0.015 | -25.25*** | -0.032 | -.145*** | 15.96*** | .323*** | .501*** |
| **Taipei** | 13.05*** | .054*** | .063*** | -2.86** | .028* | 0.013 | -5.28*** | .040* | -0.014 | -17.96*** | 0.02 | -.053*** | 10.14*** | .417*** | .561*** |
| **Macau** | 23.18*** | .123*** | .107*** | -9.43*** | -0.015 | -0.032 | 0.2 | .041* | -.047* | -25.10*** | .070** | -.069*** | 13.09*** | .291*** | .528*** |
| **Korea** | 16.61*** | .100*** | .124*** | -14.45*** | -0.015 | -.049** | -2.06 | -0.014 | -0.005 | -18.27*** | 0.013 | -.058** | 17.79*** | .394*** | .536*** |
| **Japan** | 7.13*** | .102*** | .087*** | -15.31*** | -0.026 | -0.025 | 1.92 | 0.034 | 0.029 | -10.47*** | 0.037 | -.056* | 18.52*** | .351*** | .601*** |

*p<0.05 **p<0.01 ***p<0.001

Application was the only pedagogy that was positively associated with cognitive performance in all East Asian regions (Table 8). Hong Kong students increased by an average of 23 points in total scores for each additional unit of application in class, whereas it was only about 7 points for Japanese students. Besides scores in cognitive tasks, application was also positively correlated with self-concept and enjoyment of science in all East Asian regions. It suggests that more application of science concepts in class can facilitate science learning through enhancing the motivation of students. This would be particularly important for East Asian regions since they were less application-focused as compared to the western ones (Table 7).

In most of the East Asian regions, hands on activity did not significantly associate with good performance or attitudes. Worse still, investigation showed negative associations with performance in all East Asian regions; every additional unit of investigation saw a drop of as high as 25 points in total scores. Investigation was also found negatively associated with enjoyment of science learning. These findings are in line with other secondary analyses of PISA data (Seidel et al., 2007; Taylor et al., 2009).

Hands on activity and investigation are generally seen as the crucial part of science instruction, but the findings of PISA have cast doubt on their importance, at least in the East Asian classrooms. Investigation, in particular, should be an important way to learn about the process and nature of science, so it is puzzling why it has large negative relationships with performance and attitudes. A review of the effects of practical work concludes that "most of the evidence does not support the argument that typical laboratory experiences lead to improved learning of science content" (Singer et al., 2006, p.88). One probable reason is that hands on activities and investigation actually done in science class are far from desirable to produce the effects they purport to have on understanding about the content, process and nature of science. Much of the practical work done in science class only involves manipulation of materials rather than ideas, and does not interweave with other learning activities such as lecture and class discussion to form an integrated learning unit (Singer et al., 2006, p. 82). The TIMSS 1999 Video Study found that the US classrooms were filled with a variety of activities that were not much connected with the learning of science ideas (Roth et al., 2006), which partly accounted for the unsatisfactory performance of the US in the international assessments on science. On the other hand, typical laboratory work often stresses procedure and manipulation skills more than the complex scientific inquiry processes such as formulating investigative questions and hypothesis, designing experiment, and critically evaluating the conclusion (Klopfer, 1990, in Singer et al., 2006). This kind of recipe-type experiments is limited in fostering the scientific reasoning skills of students. In addition, regarding the learning about the nature of science, the implicit approach through merely doing investigation has been shown to be largely ineffective in enhancing one's understandings about the nature of science (Lederman, 2007). Finally, even when experiments and scientific investigations are done properly, it seems that it is not the more the better (Taylor et al., 2009). A case in point was France, which was found relatively strong in knowledge about science in PISA 2006 due to its curricular and instructional emphases on investigation, but France was not ranked high in overall scientific literacy as a result of its low performance in knowledge of science (Olsen & Lei, 2009). It is probable that doing experiments and learning contents are competing for the precious class time: extended, open-ended scientific investigation, when heavily conducted in class, may come at the expense of the time for content learning.

Investigation and practical activities in class are also not necessarily enjoyed by students. Studies using the Science Laboratory Environment Inventory revealed that students' positive perceptions of laboratory experiences were strong associations with cohesiveness (students are supportive of each another) and integration (laboratory work is integrated with theory learning) (Singer et al., 2006, pp. 95-98). Therefore, how the laboratory work is done seems more important than its quantity in impacting students' attitudes.

Interaction in classroom also showed negative relationships with performance in all East Asian regions. Japan and Korea not only had the least interactive lessons, but also the largest negative associations with performance: for every one additional unit of interaction in class, there was a drop of about 15 points in overall scores. Interaction was also found not positively related to self concept and enjoyment of science learning in most of the East Asian regions.

It would be difficult to interpret why interaction in class, a widely valued pedagogy, would relate to learning negatively in all of the East Asian regions. One possible answer is that interaction, measured by PISA as student expression of ideas in class, may not necessarily lead to effective learning, particularly when it is not explicitly connected with conceptual change pedagogies. There exists a huge gap between actual classroom practices and practices as informed by the conceptual change theory (Duit & Treagust, 2003). Research on classroom talk also reveals that interaction in class is often authoritative rather than dialogic, not probing into and working on students’ ideas adequately for concept construction (Scott, 1998; Mortimer & Scott, 2003). Even worst, interaction in class is sometimes not connected with any content learning but used as a means of engaging and disciplining students. Interaction in these manners would at best enhance motivation, but risks rendering learning nonsystematic and inefficient. In the East Asian classrooms that emphasize obedience, teacher authority and diligence, too much interaction may therefore be construed as unnecessary impediment to learning by both teacher and students. Nonetheless, the interpretation can be the other way around: teachers tend to teach more interactively when faced with the less-disciplined, lower ability students in order to get them motivated in class.

## Learning time

The performance of the East Asian students is often attributed to their diligence. With respect to the formal science lesson at school, over 40% of Hong Kong and Macau students took four or more hours of science lessons a week, which was higher than the OECD average of 32.7% (Table 9). Other East Asian regions, however, had similar or lower proportions of students in that respect. The East

Asian students also did not study any harder on homework or self-study than their counterparts in the OECD countries. However, when looking at the out-of-school lessons, East Asian regions except Japan had a much higher proportion of students spending a substantial amount of time on tutorial class than the OECD average (OCED, 2007, p.55). The prevalence and importance of tutorial class, or shadow education in Asian countries have been well documented and researched (Mark & Chad, 2012). Interestingly, these after school tutorial lessons differed not only in quantity, but also in their roles for the East Asian regions and western countries. East Asian regions except Japan had more top performers taking out-of-school lesson than low performers, but it was the reversed for the western countries (OCED, 2007b, p.55). It seems that East Asian students tended to see tutorial class as a "booster" of performance for the top performers, whereas Western students deem it more as a "remedial" measure for the low performers.

Using the data from PISA 2012, we can understand better the learning time of the students. Though these data were for math class, but they were likely applicable to the science class as well. In the survey of truancy in PISA 2012, virtually no students of the East Asian regions had skipped a day of school in the two week prior to the PISA testing, as compared to 15% across the OECD countries (OECD, 2014). This had reflected that the importance of education has been deeply ingrained in the minds of the students, teachers and parents of the East Asian regions. The data in PISA 2012 also showed that East Asian classrooms were less disordered and less noisy than that of the average OECD countries (Table 10). The attentiveness in class, together with other time factors discussed above, had given East Asian students much more actual learning time at school and after school than their Western counterparts.

**Table 9.** Time students spent on learning science in PISA 2006

| | Students having 4 or more hours of science lesson a week at school (%) | Students having 2-4 hours of out-of-school science lessons a week (%) | Students having 2-4 hours of self study/homework a week (%) |
|---|---|---|---|
| **HK** | 40.2 | 12.4 | 18.3 |
| **Taipei** | 27 | 14 | 17.6 |
| **Japan** | 12.2 | 3.4 | 5.4 |
| **Korea** | 35.7 | 18.8 | 14.9 |
| **Macau** | 45.6 | 10.8 | 17.3 |
| **OECD average** | 32.7 | 8.2 | 18.6 |

**Table 10.** Classroom discipline surveyed in PISA 2012

| | There is noise and disorder in my math lessons (% of every/most lessons) |
|---|---|
| Japan | 10.73 |
| Korea | 30.28 |
| Hong Kong | 18.65 |
| Taipei | 28.12 |
| Singapore | 28.18 |
| Vietnam | 10.53 |
| Shanghai | 13.47 |
| Macau | 15.42 |
| OECD average | 31.71 |

## Class size

Large class size is a sweeping feature of the East Asian regions. This can be seen indirectly from the data of PISA 2012 that showed the size of the language class. While very few OECD countries had class size bigger than 36, the East Asian regions had 40% to 80% of classes having more than 36 students (Table 11). Vietnam, Shanghai and Taipei had even a significant proportion of classes bigger than 40. Given that these East Asian regions top in the PISA tests, large class size seems not a big problem for their performance.

**Table 11.** Class size of test language class in 2012

| | 36-40 students (%) | 41-45 students (%) |
|---|---|---|
| Japan | 55.2 | 12.95 |
| Korea | 40.72 | 5.65 |
| Hong Kong | 44.26 | 3.5 |
| Taipei | 27.7 | 22.78 |
| Singapore | 75.15 | 2.57 |
| Vietnam | 13.46 | 36.52 |
| Shanghai | 32.3 | 19.56 |
| Macao | 51.7 | 13.47 |
| OECD average | 5.33 | 2.14 |

# Discussion and conclusion

Through the lens of PISA, we can have a general picture of the science education of the East Asian regions. First of all, their science performance is definitely very good, with many of them consistently ranked within the top ten in the PISA tests, having a large proportion of top performers, and improving steadily in the past decade. Although East Asian students generally have low self concept on learning science, Chinese students are nevertheless more interested in and value science learning as compared to their Japanese and Korean counterparts. In the East Asian classroom, science teachers tend to teach more traditionally: fewer hands on and investigative activities, less interaction and less emphasis on the application of science. Interaction seems not an effective pedagogy in the East Asian classroom - the more the lesson is interactive, the poorer the students perform, particularly for Japan and Korea. Hands on activity, though not clearly conducive to science achievements, is associated with enjoyment of science learning for Chinese students. Common in East Asian regions is that student performance and enjoyment get enhanced whenever there is more application of science in class. Scientific investigation, to the contrary, is negative to both performance and attitudes in all East Asian regions. The class sizes of the East Asian regions are large as compared to their western OECD counterparts. However, students are attentive in class and there is less disorder and noise. East Asian students often spend lots of time on after-school tutorial classes, which, together with less truancy and greater attentiveness in class, render their actual learning time more than the western students.

The above characteristics of the East Asian education could be better understood with the literature about Chinese learners and teachers and the Confucian Heritage Culture. The paradoxes of the Chinese learners and the Chinese teachers were raised and thoroughly discussed in the three books: The Chinese Learner (Watkins & Biggs, 1996), Teaching the Chinese Learner (Watkins & Biggs, 2001) and Revisiting the Chinese Learner (Chan & Rao, 2009), in which some of the myths of the stereotyped Chinese learners and teachers were debunked. Chinese students do not learn by rote but seek understanding through repetition and memorization. They are motivated both extrinsically and intrinsically by not only individual interest and ambition, but also by social, family and peer expectations. Despite more extrinsically motivated, Chinese students do not necessarily use surface approach to learning; instead, many were found using deep learning approach. Chinese teachers are indeed more authoritarian in classroom, but it was found that good teacher-student relationships are built up through informal interactions outside classroom (Ho, 2001). Given this and the Confucian culture of obedience and respect for teachers, a more teacher-controlled classroom may not necessarily be negative for the Chinese students as construed from the western perspectives; rather, it can make learning more efficient. Besides, a more teacher-controlled lesson is not necessarily passive and didactic; instead, the Chinese teachers carefully orchestrate direct teaching, whole class discussion and group activities in the lesson, which, albeit teacher-centred, can engage students actively in learning (Mok et al., 2001). It is therefore a wrong belief that Chinese teachers and students only aim at memorization without understanding. At last, the intense examination pressure in most Asian education systems might not be negative since it is in alignment with the Confucian culture that stresses efforts, diligence and personal success through education.

Nonetheless, there are variations within the East Asian regions as a result of each region’s unique socio-cultural-political context and the “vernacular Confucianism” (Chang, 2000) developed under it. Japanese and Korean students are different from their Chinese counterparts in many ways: much lower enjoyment and self-concept in science, much less common of the four pedagogies in class, and relatively better in identifying scientific issues and weaker in explaining phenomena scientifically. Though Japan and Korea are still performing strongly in PISA, their students' low enjoyment and interest in science learning may be a concern for sustained performance.

The success of these East Asian regions may be a result of the great efforts they put into the reforms of curricula and school systems in recent decades (Strong Performers, 2013), though more research evidence is still needed to make the connection. Hong Kong had initiated drastic changes in curricula and school structures in 2001, emphasizing joyful learning and learning to learn. Shanghai has put in great efforts in enhancing classroom teaching, in which teachers form teaching-study groups, led by experienced, expert teachers, to prepare lessons collaboratively. Singapore's reforms focus particularly on math, science and technical skills, and, more importantly, on the quality of teachers. Korea's Smart Education has a strong focus on ICT. Japan started "relaxed education" in 2002 with an emphasis on creative thinking, but it was later revised to pay greater attention to basic knowledge and Zest for living. Besides, teachers in Japan are well paid and have ample time for non-teaching work.

Since the characteristics of the East Asian education have their root in their unique sociocultural heritage, it would make no sense of the western countries to "transplant" these "success formula" to their education systems. For instance, the East Asian students could benefit to some extent from the teacher-dominated, expository instruction in a disciplinary classroom, but these may be detrimental for the western students, who would otherwise learn better when the class is interactive and hands on. The East Asian students, despite low in self-concept, could still enjoy learning and perform well since the pressure and challenges have driven them to put in greater efforts rather than to withdraw; the western students, on the other hand, may benefit more from a relaxing classroom culture with less rigorous content standards so that their self concept can be protected. An East Asian classroom can seat in more than 40 students yet teaching and learning can proceed effectively, but it does not mean that such a large class size works for the western students. Therefore, we need to seek culturally appropriate ways to make the best out of a country's characteristic profiles of students, teachers, parents, schools and educational system.

One major drawback of the education in these East Asian regions is the extremely high examination pressure and the accompanying exam-oriented, competitive learning environment. The performance may come at a cost of self concepts and interest in learning, creativity and various important life skills such as independent learning and problem solving skills. If it is true, whether these top science performers can sustain their performance in their life-long learning is called into doubt.

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