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The PISA View of Mathematical Literacy in Indonesia

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Abstract

PISA, the OECD's international program of assessment of reading, scientific and mathematical literacy (www.oecd.org/pisa), aims to assess the ability of 15 year olds to use the knowledge and skills that have acquired at school in real world tasks and challenges. It also uses questionnaires to gather data on students' attitudes to learning and the conditions of schooling. Since 2000, PISA has tested the mathematical literacy of 15 year old students from many countries around the world. This paper describes the design of the PISA assessments, discusses mathematical literacy and reports on a selection of results from the PISA assessments, associated surveys and related analyses to give a flavour of the information that has resulted from this major international initiative. Results for Indonesia are compared with the OECD average and with a selection of countries, addressing issues of overall achievement, equity, and classroom environment.

Abstrak

PISA, adalah program internasional OECD untuk mengevaluasi kemampuan membaca, sains dan matematika (lihat www.oecd.org/pisa), bertujuan untuk mengetahui kemampuan anak usia 15 tahun dalam menggunakan kemampuan dan keahlian yang telah mereka pelajari di sekolah dalam menjalani kehidupan mereka sehari-hari di zaman global yang penuh tantangan. Program ini juga menggunakan angket untuk mendapatkan informasi terkait sikap siswa untuk belajar serta kondisi sekolah. Sejak tahun 2000, telah mengases kemampuan matematika siswa usia 15 tahun dari berbagai negara di dunia. Paper ini menjelaskan bagaimana soal PISA dibuat, mendiskusikan literasi matematika dan melaporkan hasil PISA untuk beberapa negara tertentu, hasil analisisnya untuk memberikan pemahaman mendalam yang telah dihasilkan dari program internasional ini. Hasil siswa Indonesia dibandingkan dengan rata-rata negara OECD serta beberapa negara yang dipilih, terkait pemahaman secara umum, kebersamaan dan lingkungan kelas.

Introduction to PISA

PISA is the acronym for the 'Programme for International Student Assessment', organised by the OECD in conjunction with a group of other participating countries, including Indonesia. The first survey took place in 2000, and then every 3 years since that time. PISA measures knowledge and skills of 15-year-olds, an age at which students in most countries are nearing the end of compulsory schooling. The focus is on areas that are important for life after school, including mathematics. PISA is a statistically rigorous programme to assess student performance and to collect data on the student, family and institutional factors that can help to explain differences in performance in countries around the world. Substantial efforts and resources are devoted to achieving cultural and linguistic breadth and balance in the assessment materials. Stringent quality assurance mechanisms are applied in translation, sampling and data collection to ensure that the results are as meaningful as possible. The aim is to significantly improve understanding of the outcomes of education in the OECD countries, as well as in a growing number of countries at earlier stages of economic development who are choosing to participate.

The OECD identifies the key features of PISA as:

- policy orientation, with the major aim of informing educational policy and practice;
- the PISA concept of “literacy” (see below) with a foundation of assessment of literacy for reading, mathematics and science;
- its relevance to lifelong learning, so that assessment of knowledge is supplemented by reports on motivation to learn, attitudes towards learning and learning strategies;
- its regularity, enabling countries to monitor improvements in educational outcomes in the light of other countries’ performances on assessments held every 3 years;
- measurement of student performance alongside characteristics of students and schools, in order to explore some of the main features associated with educational success;
- breadth, with over 60 countries and economies participating by 2009, representing around 90% of the world economy.

PISA is one of two major international assessments of mathematics and science achievement, the other being TIMSS (http://timss.bc.edu/), which has assessed Grade 4 and 8 students (and sometimes Grade 12) regularly since 1994/1995. A major difference is that TIMSS aims to make an assessment of the (common aspects of the) mathematics curriculum as taught in participating countries, whereas PISA starts from concern for the mathematical literacy (see below) that is judged to be valuable to 15-year-olds for their lives.

Four PISA surveys have taken place so far, in 2000, 2003, 2006 and 2009, focusing on reading, mathematics literacy and science literacy and this three year pattern will continue. In each assessment year, one of these three ‘literacies’ is the major focus. The cycle began with reading in 2000, mathematics in 2003 and science in 2006. The 2009 assessment represented a new round, with reading again the major focus. PISA 2012 will focus on mathematics as the main domain as in 2003. In each assessment, trend data is collected through an abbreviated test on the other two domains, using ‘link items’ from the earlier assessment to give results that can indicate trends.

Students also answer a 30 minute background questionnaire, providing information about themselves, their attitudes to learning and their homes. School principals answer a questionnaire about their schools. These questionnaires provide baseline information about the conditions of schooling in different countries, and enable the examination of issues such as equity of schooling and effective practices.

PISA is also developing other assessments. For example, it measures Information and Communication Technology skills and assesses the reading of electronic texts. In 2012, there will be an optional component on financial literacy. Since the science assessment of 2006, computer-based assessments have also been used to support a wider range of dynamic and interactive tasks. The mathematics assessment for 2012 will have an optional computer-administered component, which will provide new opportunities for presentations of items and may also test some aspects of doing mathematics assisted by a computer. The 30th meeting of the PISA Governing Board in November 2010 proposed “moving PISA from a paper-based assessment towards a technology-rich assessment in 2015 as well as from traditional item formats to the kind of innovative assessment formats which computer-delivery would enable (OECD 2010b). PISA has also conducted tests of general problem solving, and will do so again in 2012. The problem solving assessment taps students’ “capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the literacy domains or curricular areas that might be applicable are not within a single domain of mathematics, science or reading” (OECD 2003b, p. 156). The mathematics assessment also contains many items that might be considered problem solving, but they draw explicitly on mathematics content.

Participating Countries and Students

All OECD countries have participated in PISA since its inception in 2000. As a partner country Indonesia has also participated since 2000. There is growing participation by Asian countries in PISA. Asian countries have been prominent for over a decade in the TIMSS assessments, with public attention attracted by some very high Asian performances. By 2009, the Asian countries participating in PISA were the OECD countries Australia, Japan and Korea and the partner countries Indonesia, three parts of China which are considered as separate economies (Hong Kong, Shanghai and Macao), Chinese Taipei, Malaysia, Singapore, and Thailand. Two parts of India (Himachal Pradesh, Tamil Nadu) and Viet Nam participated in the survey late. In 2009, there were 65 participating countries made up of 34 OECD countries and 31 partner countries and a further 9 completing late.

Schools in each country are randomly selected by the international contracting consortium for participation. At these schools, the test is given to all students who are between age 15 years 3 months and age 16 years 2 months at the time of the test, rather than to students in a specific year of school as with TIMSS. The selection of schools and students is kept as inclusive as possible, so that the sample of students comes from a broad range of backgrounds and abilities. The sampling is carried out very strictly. Sometimes the results of countries that participated in the surveys are not included in all of the analyses, because they failed to meet the strict sampling criteria. For example, even though PISA tests were conducted in the Netherlands in 2000, the response rate of schools was below that required for inclusion and thus the Netherlands is excluded from trend analysis beginning with PISA 2000.

There are many ways in which the design of the sample impacts on the results, and these need to be considered, especially when comparing results from different countries, or when comparing results from TIMSS and PISA. PISA selects students by age, rather than sampling whole classes within grade levels as is used by TIMSS. Hence a survey of teachers is not as appropriate for PISA as it is for TIMSS, although a survey of the school is informative, especially in locations where 15-year-old students have usually attended that school for some time. In this circumstance, the outcomes of student learning could be expected to have been strongly influenced by actions taken at that school, and so the school questionnaire should reveal information about conditions to teach mathematical literacy well. Both age and number of years of schooling affect performance of students and so the difference in sampling methods of TIMSS and PISA is one reason for the moderate differences in the rankings that they produce. This is pertinent when comparing the results on TIMSS and PISA for the Australian states, for example. In some states, 15-year-old students have spent more years at school than in other states and hence are probably in a higher grade level. These factors need to be considered and accounted for, before concluding that there are important differences in the knowledge and skills attained in different school systems (Stacey & Stephens, 2008). School policies about progression also affect the sampling. In some countries, almost all students of a given age are in the same grade, but in others, including Indonesia, nearly half of the 15-year-olds are not in the modal grade. (OECD 2010a, Vol IV, Table IV.3.1).

Surveys, Questionnaires, and Reporting

PISA surveys are made up of both multiple-choice questions and constructed response questions. Each PISA survey includes about seven hours of test material but individual students each do a two-hour subset of this. Country and other group results are constructed by combining these results. Since different students do items of potentially different difficulty, the results of individual students on PISA tests are not meaningful.

In mathematics and science, the test items are grouped into units which start by describing a real world situation or problem. Mathematics units usually begin with a description of a situation that might be encountered in real life in words and pictures and possibly symbols (e.g. a map for a journey, authentic tables of data, plans for a house), a formula to calculate something practical) and a series of questions requiring students to use this information, for example, to calculate quantities and interpret results, with all aspects having face validity as sensible ways to use mathematics. RISING CRIMES, a sample mathematics unit (OECD 2006, p. 94) begins with a very striking stylised graph of reported crimes per 100 000 inhabitants of a town. For item 1, students have to read a point from the graph. For item 2, a second graph of the same information is given, supposedly produced by manufacturers of burglar alarms. Students have to identify features such as how the graph has been altered to convey a message. A non-linear scale was used. They then have to construct a graph which the police could use to show from the same data that crime has recently decreased. This unit is about interpretation of information provided by graphs and it also requires students to analyse how the visual appearance of the graph can be manipulated (e.g. by graphing only a subset of the range) to emphasise a particular message.

This type of item illustrates ‘mathematical literacy’ since it is highly relevant to the way in which citizens in all societies need to be able to deal with information presented in the media. Another unit, STUDENT HEIGHTS (OECD 2006, p. 104), gives information about the average height of students in a class, and the ranges and averages for boys and girls both when the whole class is present and when two students are absent. Students have to evaluate the truth of several statements about who was absent. A sample science item (OECD 2006, p. 28) begins with a simplified newspaper article about catching a killer using a DNA profile of a blood sample from the crime scene. Students are asked to select the correct definition of DNA in a multiple choice format, and identify those questions about the crime which can be answered by scientific evidence. Another unit, MALARIA, provides a substantial text about the seriousness of the disease malaria, and about the life cycle of the malaria parasite in words and pictures. Students have to categorise methods of preventing the spread of malaria according to the stages in the life cycle of the parasite that are affected (OECD 2006, p. 30).

A total of 85 mathematical literacy items were used in PISA 2003, with about half the items also included in the 2006 and 2009 PISA assessments, so that the trends in performance can be reported. The common items assessed in each cycle provide a link that enables the monitoring performance across and within countries over time. Ninety minutes of the assessment time were devoted to mathematical literacy in PISA 2009, although not for any one student. In 2003 and again in 2012 when mathematics once again the major domain, the total assessment time for mathematics will be 270 minutes. Many new items are in the preparation and field testing for the 2012 assessment.

Many of the PISA items are kept secure, so that they can be reused to create the trend data that is so valuable for governments monitoring progress in education systems. However, some items have been publicly released from every survey. Accessible from the PISA website and also downloadable as a booklet, *PISA Take the test* (OECD 2009b) presents all the publicly available questions. Some of these questions were used in the PISA 2000, 2003 and 2006 surveys but will not be used again, and others were used in trials but for some reason have not been included in the main survey. There are many reasons why an item might not be included in the final assessment and hence may be publicly released. For example, it may have not worked well in many or a few countries, it may have been too difficult or too easy, or there may have already been sufficient items with its characteristics so that it was surplus to requirements.

PISA scores are reported along specific scales that are divided into levels, beginning at Level 1 with questions that require only the most basic skills to complete and increasing in difficulty with each level. In each test subject, the country score is the average of all student scores in that country. Some statistical adjustment is applied. The percentage of students at each level is also reported. Using Räsch measurement principles, the same scale is used to describe student ability and the difficulty level of each of the items. The scores have been arranged so that the average score among OECD countries is 500 points and the standard deviation is 100 points. As might be expected from economic factors, many of the non-OECD participating countries have lower scores. About two-thirds of students across OECD countries score between 400 and 600 points. When the 2009 results were released (OECD 2010a), all observers were stunned when the municipality of Shanghai (China) obtained an average score in mathematics of 600, far out performing even the previous stand-out countries of Chinese Taipei (score 543), Finland (541) and Hong Kong-China (555).

The continuum of increasing mathematical literacy from Level 1 to Level 6, with summary descriptions of the kinds of mathematical competencies at sample levels of proficiency, is shown in Table 1. A difference of about 60 score points represents one proficiency level, and 40 score points corresponds to about one year of schooling (OECD 2004, p. 60).

Table 1. *Description of mathematical literary of students at sample proficiency levels* [From OECD 2009c, p. 122]

Level 6 (over 669.3 score points)	At Level 6, students can conceptualise, generalise, and utilise information based on their investigations and modelling of complex problem situations. They can link different information sources and representations and flexibly translate among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understandings along with a mastery of symbolic and

	formal mathematical operations and relationships to develop new approaches and strategies for attacking novel situations. Students at this level can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situations.
Level 4 (over 544.7 score points)	At Level 4, students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic, linking them directly to aspects of real-world situations. Students at this level can utilise well-developed skills and reason flexibly, with some insight, in these contexts. They can construct and communicate explanations and arguments based on their interpretations, arguments, and actions.
Level 2 (over 420.1 score points)	At Level 2, students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and making literal interpretations of the results.

Information About PISA

A great deal of information about PISA is publicly available. The publicly released items are available at *PISA Take the test* (OECD 2009b), and the main website provides most reports as free downloads (http://www.pisa.oecd.org/). The 'MyPISA' site is the portal to see all the instruments used in the questionnaires, complete databases, published reports and also for a free data analysis service, where specific queries related to countries can be submitted for immediate response (http://mypisa.acer.edu.au/).

The PISA Concept of Mathematical Literacy

PISA (OECD 2006) defines mathematical literacy as an individual's "capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments, and to engage in mathematics in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen." (p. 16). This definition will be refined and updated for the 2012 assessment. Whilst mathematical literacy is intended to highlight mathematical skills and understanding that are of use in future life, the intention is not to refer only to simple mathematics involved in straightforward activities such as shopping: it also encompasses preparation to use mathematics in technical professions of the highest level.

The concept of mathematical literacy is closely related to several other concepts discussed in mathematics education. The most important is mathematical modelling (related to mathematisation by de Lange, 2006) and its component processes. These processes relate to *formulating* real world problems in mathematical terms so that they can be *solved* as mathematical problems, and then the mathematical solution can be *interpreted* to provide an answer to the real world problem. In the formulation stage, the problem solver faces a problem situated in a real context, and then gradually trims away aspects of reality, recognising underlying mathematical relations, and describes the stripped down problem in mathematical terms. In the interpretation stage, the problem solver considers the mathematical result(s), and uncovers their meaning in terms of the real context. Mathematical modelling has been an important concern amongst mathematics educators for many years (see, for example, Blum, Galbraith, Henn & Niss, 2007). Where mathematical modelling is seriously taught, students spend substantial time on one problem, moving through the whole cycle from formulating the problem mathematically, to solving it in mathematical terms and then interpreting and critiquing the solution. This critique might even demonstrate the need to begin again with a better formulated mathematical model. A key challenge for PISA is that it embraces the goals of mathematical modelling, yet it is not possible to ask substantial modelling questions under the constraints of timed assessment and the demand that results be amenable to standard statistical analysis. Only relatively short units that highlight some of these component skills can be used.

Mathematical literacy is also associated with the concept of numeracy, which is especially prevalent in countries influenced by the British tradition. To give an example, in Australia the term *numeracy* is often used synonymously with mathematical literacy. In fact, though, different authors give it meanings ranging from a narrow ability with number to a very ambitious goal of using mathematics in many different situations (Willis, 1990). In the United States, researchers concerned about the preparation of students for living have used terms such as *quantitative literacy* (Steen, 2001). PISA's mathematical literacy, however, is not meant to imply a low-level basic competency. Instead, individuals in all walks of life need mathematical literacy, to different degrees in different occupations and life choices.

Items for PISA mathematics are currently described on several dimensions. Attending to these dimensions ensures that the test is balanced against important criteria, as well as ensuring that the test remains true to the criteria for mathematical literacy. There are three main components in the framework that has been used up to 2009, although some changes are underway for 2012. One component is 'overarching idea' which classifies problems according to the content and purpose behind the use of mathematics, noting whether it deals with *quantity, uncertainty, change and relationships* or *shape and space*. These divisions are loose, but broadly align with the driving ideas behind the curriculum in most countries. The purpose of using 'overarching idea' rather than the labels of syllabus topics is to highlight the nature of problems that mathematics contributes to solving. So for example, there are many syllabus topics that assist in solving problems related to the overarching idea of 'change and relationships': derived quantities and units (e.g. speed, density), rates of change, ratio, calculus, algebraic functions). These syllabus topics could also be useful in solving problems related to the other overarching ideas. It is the underlying character of the problem, not the mathematical topic(s) involved that determines the 'overarching idea' allocated to a problem.

Another dimension is to classify the situation or context in which the items are embedded. These are classified (OECD 2006) as personal (related to everyday life), educational/ occupational (which might include contexts from other school subjects or the work of someone such as a bricklayer), public (e.g., a context relating to interest rates) and scientific (e.g. interpreting a graph about the growth of microorganisms). A key question for PISA, which stresses the usefulness of mathematics for life, is to what extent intra-mathematical items are allowed. Should every item have a clear reference to a situation beyond mathematics, or a simplification of one? Or can some items belong entirely to the mathematical world? Whereas TIMSS items test the curriculum (so solving an equation such as $9x + 6 = x + 14$ is a reasonable question), PISA items test knowledge in context. There are few PISA items with a context entirely within mathematics.

Choice of PISA items in mathematics also raises issues of the interpretation of the 'educational context'. This is because mathematics is taught at school both for immediate use and as preparation for future study. Governments wish to know how well schools are preparing students in both these respects. It is not in the spirit of PISA to include an item only requiring students to solve a quadratic equation, for example, although such decontextualised mathematics is typical of the formal preparation for future study actually given in many countries and schools. As such, PISA might be seen as being out of step with mathematics as it is taught in some classrooms. For some, this is a criticism but is better viewed as an inspiration to shift mathematics teaching so that students are more likely to be able to use what they learn.

PISA and Curriculum Content

The intention of PISA is to measure how well students are prepared at school to use what they have learned to analyse and reason as they interpret and solve problems in a variety of situations encountered in life. Of course, in order to assess mathematical literacy of 15-year-olds, there is a need for items to be within the capacity of 15-year-olds in participating countries, and hence to correspond with school curricula in a broad sense. Items must also take into account the interests and knowledge of the world that 15-year-olds are likely to have encountered. Saying that the PISA assessments are not designed around school curricula does not imply that either the survey items or the results are not influenced by them. For example, Wu (2010) showed how countries' national performance is affected by the alignment of its curriculum with the PISA assessment. Australia, for example, usually does well in the assessment of mathematical ideas of chance and the interpretation of data, and these topics are well represented in the Australian curriculum. Studies such as this reinforce the view that if scientific and mathematical literacy are regarded as valuable outcomes of schooling, then they should be well represented in intended and implemented curricula.

PISA Mathematics Scores

As is to be expected from such enormous collection of data (approximately 470 000 students in 2009), PISA produces many results. Rankings are always of interest, even though there are many complex factors that contribute to students' proficiency. In this paper, results for Indonesia are compared with the OECD average and with the results for some neighbouring countries (Australia, Hong Kong-China, Japan and Thailand). Finland is also included because it has received much attention as a consistently very high-ranking OECD country in all three literacies.

With the results from four cycles of PISA testing now available, trends over time are becoming increasingly valuable. Figure 1 shows the mean scores for mathematics, science and reading for Indonesia for each of the four PISA assessments. The standard deviations are between 66 and 85. There has been a steady increase in mean scores for the reading scale since 2000. The increase of 31 points from 2000 to 2009 is the fourth largest increase of any country for reading (OECD 2010a, Vol. V, Figure V.2.1, p. 39). The 2009 mean for science shows a drop of 10 points from a fairly stable level in the previous three assessments. A small decrease like this in a country's score is not uncommon, but it is surprising when compared with the consistent gains made in reading in Indonesia. The mathematics score has been more unstable. One way of interpreting the data is that it has been steady, except for a relatively high score in 2006. The summary report for PISA 2006 noted that the high scores in 2006 in both reading and mathematics were "largely driven by the higher performance of [Indonesian] males in PISA 2006" (OECD 2007a, p. 320). In terms of country rankings, these scores place Indonesia towards the end of the ranked list. Colombia, Albania, Tunisia, Qatar, Peru and Panama had an average score not statistically different from Indonesia's. Panama's score of 360 was the second lowest score for mathematics in 2009.

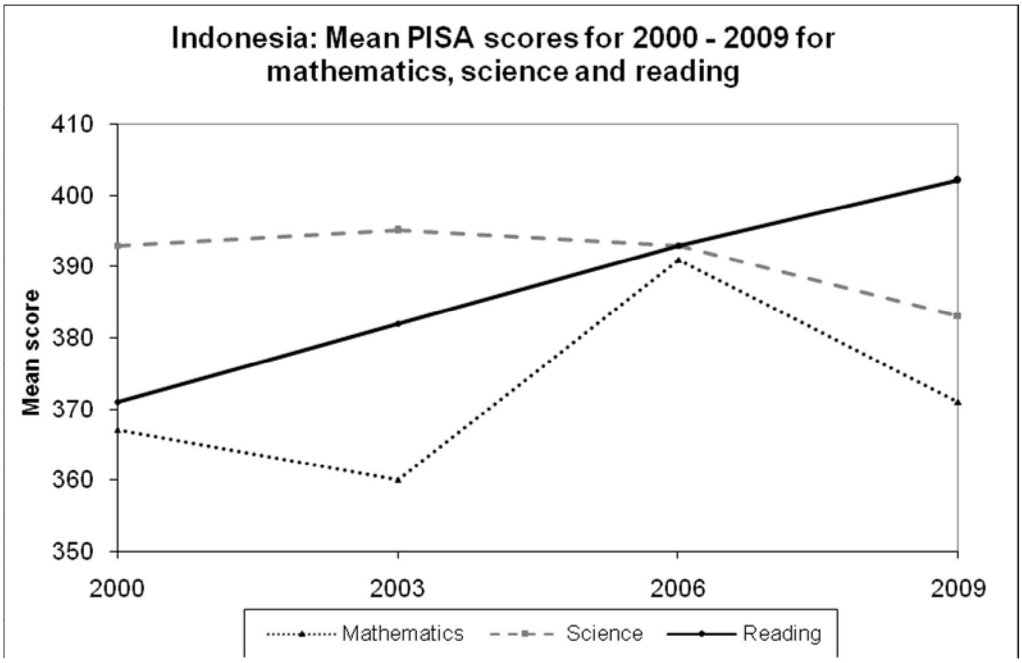


Figure 1. Mean scores of Indonesian students for mathematics, science and reading for PISA 2000 – 2009 [Data from OECD 2003a, Tables 2.3a, 3.1, 3.2; OECD 2004, Tables 2.5a, 6.2, 6.6; OECD 2007, Vol. 1, Tables 2.1c, 6.1c, 6.2c; OECD 2010a, Vol. I, Table I.2.2, Vol. V. Tables V.2.9, V.3.3].

Table 2 shows the percentages of students reaching the top two levels (Levels 5 and 6) for science, mathematics and reading in the PISA 2009 assessment. The PISA 2009 report (OECD 2010a) states that students "who get to this level can be regarded as potential 'world class' knowledge workers of tomorrow, making the proportion of a country's students reaching this level relevant for its future economic competitiveness" (Vol. I, p. 51). Indonesian 15-year-olds are not yet reaching this level.

Table 2. *PISA 2009: Percentage of students reaching the top two levels (Levels 5 and 6) in PISA 2009* [From OECD 2010a, Vol. I, Tables I.2.1, I.3.1, I.3.4]

Country	Percentage of students reaching the top two levels		
	Science Literacy	Mathematics Literacy	Reading Literacy
Indonesia	0	0.1	0.02
OECD average	**8.5**	**12.7**	**7.6**
Australia	14.5	16.4	12.8

Finland	18.7	21.7	14.5
Hong Kong-China	16.2	30.7	12.4
Japan	16.9	20.1	13.4
Thailand	0.6	1.3	0.3

At the other end of the scale, the report notes that "Level 2 represents a baseline level of mathematics proficiency on the PISA scale at which students begin to demonstrate the kind of skills that enable them to use mathematics in ways that are considered fundamental for their future development" (OECD 2010a, Vol I, p. 132). A high proportion of Indonesian students are still below level 2 at age 15. Table 3 shows the percentages of students in selected countries scoring below Level 2 in PISA 2009 for the three literacies.

On average, 22% of students in OECD countries perform below Level 2 in mathematics, but there are wide differences between countries. In 6 countries (including high performing Asian participating economies), less than 10% of students performed at below level 2. In all other OECD countries, the percentage of students performing below Level 2 ranges from 11.5% in Canada to 51.0% in Chile (OECD 2010a, Vol. I, p. 133). As noted above, as evident in Table 3, non-OECD participating countries tend to have more students at the low levels of achievement. For this reason, the 2012 assessment will have options for countries to include more items aimed at this group of students, in order to give more sensitive assessments in this range. One benefit of this strategy should be to reduce the percentage of students who judge a question to be too difficult and hence do not respond.

Table 3. *Percentage of students below Level 2 in PISA 2009* [From OECD 2010a, Vol. I, Tables I.2.1, I.3.1, I.3.4]

Country	Percentage of students below Level 2		
	Science literacy	Mathematics literacy	Reading literacy
Indonesia	65.6	76.7	53.4
OECD average	**18.0**	**22.0**	**18.8**
Australia	12.6	15.9	14.2
Finland	6.0	7.8	8.1
Hong Kong-China	6.6	8.8	8.3

Japan	10.7	12.5	13.6
Thailand	42.8	52.5	42.9

Table 4 and Figure 2 show the distributions of performance for 2009 PISA mathematics. The distribution of Indonesian students across the levels resembles the distribution for Thailand, but Thailand has approximately 20% fewer of its students in Levels 1 and 2. Looked at another way, the scores of Indonesian students are about 50 points below the Thai students across the distribution, and this is of the order of a full year of schooling difference. The mean OECD score is above the 95th percentile for Indonesian students and between the 75th and 90th percentile for Thai students.

Table 4. *Student performance for PISA 2009 mathematics, showing percentile scores* [From OECD 2010a, Vol. I, Table I.3.3]

Country	Mean	Percentiles					
		5th	10th	25th	75th	90th	95th
Indonesia	371	260	284	324	416	462	493
OECD average	**496**	**343**	**376**	**433**	**560**	**613**	**643**
Australia	514	357	392	451	580	634	665
Finland	541	399	431	487	599	644	669
Hong Kong-China	555	390	428	492	622	673	703
Japan	529	370	407	468	595	648	677
Thailand	419	295	321	365	469	522	554

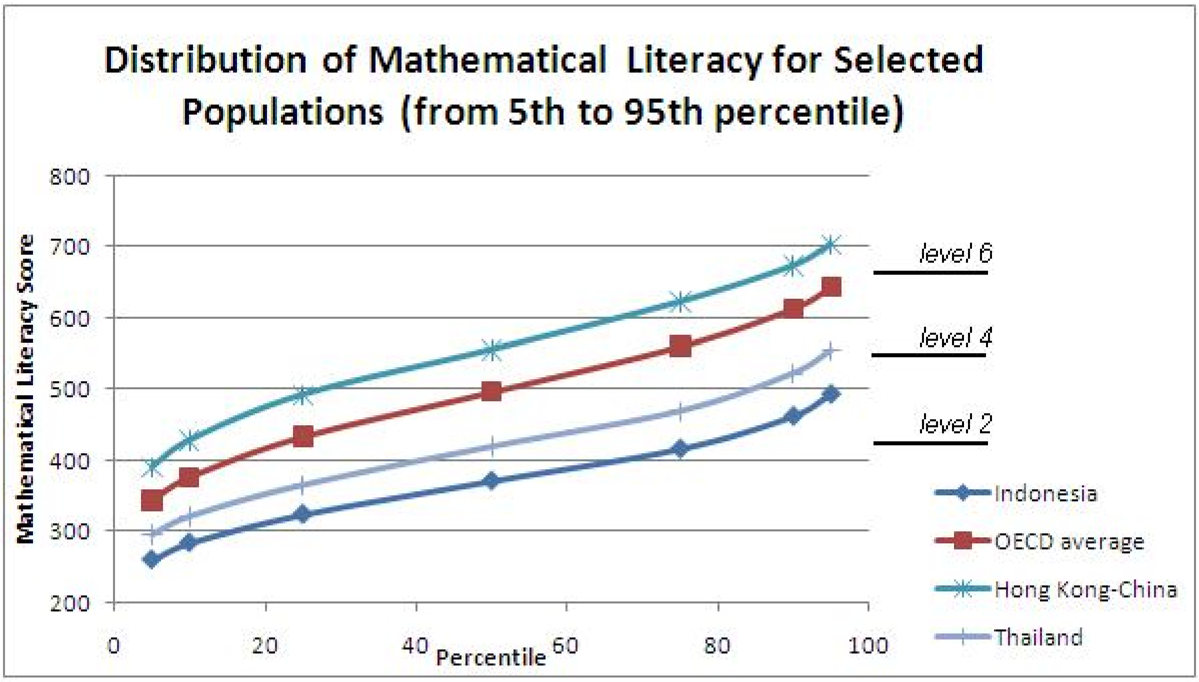


Figure 2. Distribution of mathematical literacy score for 5th, 10th, 25th, mean, 75th, 90th and 95th percentiles [Data from OECD 2010a, Vol. I, Table I.3.3].

Measures of Equity

The 2009 report (OECD 2010a) notes that there is a correlation between GDP per capita and educational performance, but this only predicts 6% of the differences in average student performance across countries. The other 94% of difference reflects the fact that countries of similar prosperity can produce very different educational results (Vol. I, p. 161). In all countries, achievement of individuals is statistically related to various factors in the individuals' socio-economic background, but in some countries this plays a greater role that in others. This can provide important information to countries about the equity of their school provision.

Parental Education

Parental education is an important predictor of achievement. PISA 2006 analysed student results according to parental education, as reported on the student questionnaire. Table 5 shows the mean scores for two groups of students: those with parents with the highest categories of education and those with parents with the lowest levels of education. Across all countries and across the three domains there are marked differences in mean scores between these two groups of students, regardless of differences in economic, social and cultural status. In Indonesia the average differences between these two groups of students are comparable with those in the high-equity country of Finland (see OECD 2007, Vol. 1, Figure 4.10, p. 189) and are smaller than for Australia, Hong Kong-China or Thailand, and considerably smaller than the average differences across the OECD. The Indonesian difference of about 40 points is approximately equivalent to 1 year of schooling.

Table 5. *Mean scores of students by parents' level of education* [From OECD 2007, Vol. 2, Table 4.7a, p. 135]

	Students whose parents have low level of education (lower secondary or less)			Students whose parents have high level of education (tertiary)		
	Science	Mathematics	Reading	Science	Mathematics	Reading
Indonesia	378	375	377	416	416	414
OECD av.	**446**	**448**	**443**	**525**	**522**	**516**
Australia	486	487	477	548	539	532
Finland	532	517	518	572	556	556
HK-China	523	529	521	575	580	561
Thailand	405	400	402	482	477	475

Socio-Economic Background

In order to summarise the influence of socio-economic background on the performances of students and countries, an index of economic, social and cultural status (ESCS) was created by combining variables such as the parents' occupational status, education, wealth, home educational and cultural resources compiled from the questionnaire data. Table 6 shows the relationship between student performance in mathematics and the PISA ESCS index for PISA 2006. For the OECD average and for the countries shown here, the score point differences between the bottom and top quarters are all statistically significant. The score point differences are equivalent to between half a year and one year of schooling on average.

Table 6. *PISA 2006: Mean scores in mathematics of students with the lowest and highest index of economic, social and cultural status (ESCS)* [From OECD 2007, Vol. 2, Table 4.11, p. 157]

Country	Students in bottom quarter of ESCS index	Students in top quarter of ESCS index	Difference in mean scores
Indonesia	366	431	65
OECD av.	**455**	**544**	**89**
Australia	482	561	79
Finland	519	585	66
HK-China	517	579	62
Japan	485	556	71
Thailand	391	466	75

A key concept developed to analyse the PISA 2003 results is that of *social gradient* (also called *socioeconomic gradient*). This is effectively the number of score points of performance that is associated with one unit of improvement in socio-economic conditions as measured by the ESCS index. In mathematics in PISA 2003 (OECD 2004), most of the Asian region countries (Hong Kong-China, Japan, Korea and Macao-China, Indonesia and Thailand) had below OECD-average social gradient. This means that the impact of socio-economic factors on student performance is less than in many other countries and, at least on a superficial interpretation, points to equity of schooling. This was again found for PISA 2009 (OECD 2010a, Vol. II, Figure II.3.4, p. 59) (except for Japan). There are many challenges for education in this region and many improvements need to be made, but the relative equity is a good characteristic of Asian educational systems. Table 7 shows the social gradient (the score point difference for mathematics associated with one unit of ESCS) and the percentage of explained variance in students' scores for the 2006 mathematics assessment and the 2009 reading assessment. For Indonesia and Thailand, the relationship between PISA score and ESCS index is distinctly curved, so that an increase of one unit in the ESCS index makes more difference to achievement at higher levels.

Table 7. *Relationship between student performance in mathematics and ESCS index for PISA 2006* [From OECD 2007, Vol. 2, Table 4.4d, p. 129; OECD 2010a, Vol. II, Table II.3.2]

Country	Social gradient (increase in maths score for one unit increase in index)		Percentage of variance in student performance explained by ESCS index	
	2003 Mathematics	2009 Reading	2003 Mathematics	2009 Reading
Indonesia	+24*	+17	10.1	7.8
OECD av.	**+38**	**+38**	**14.4**	**14.0**
Australia	+38	+46	11.5*	12.7
Finland	+32*	+31	10.0*	7.8
HK-China	+26*	+17	6.8*	4.5
Japan	+40	+40	9.4*	8.6
Thailand	+28*	+22	14.6	13.3

Gender Differences

In PISA 2009 reading, girls outperformed boys in every participating country by an average, among OECD countries, of 39 PISA score points – equivalent to more than half a proficiency level or one year of schooling (OECD 2004, p. 60). In contrast, gender differences in mathematics generally favour boys, but Indonesia is one country where there has been very little or no difference. This is another equity measure where differences common in other countries are less in Indonesia. On average across OECD countries, boys outperformed girls in mathematics by 12 score points in PISA 2009. However, there is considerable variation between countries as shown in Table 8. In PISA 2009, Indonesia is one of only 11 countries where the difference is in favour of girls, although this was not the case in PISA 2006.In PISA 2006, the averages for boys and for girls were both above other years, but boys outperformed girls by 17 score points. In contrast with the reading results, in mathematics there are more boys (6.6%) than girls (3.4%) amongst the top performers in the OECD countries (OECD 2010a, Vol. I, Table I.3.8). For Indonesia the corresponding percentages are 0.1% and 0.0%. The mean scores by gender for Indonesia over three cycles are shown in Figure 3.

Table 8. *Gender differences in scores for mathematics in PISA 2009* [From OECD 2010a, Vol. I, Table I.3.3, p. 224]

Country	Mean All	S.D.	Mean score Boys	Mean score Girls	Score difference (B – G)
Indonesia	371	70	371	372	-1
OECD av.	**496**	**92**	**501**	**490**	**12**
Australia	514	94	519	509	10
Finland	541	82	542	539	3
HK-China	555	95	561	547	14
Japan	529	94	534	524	10
Thailand	419	79	421	417	4

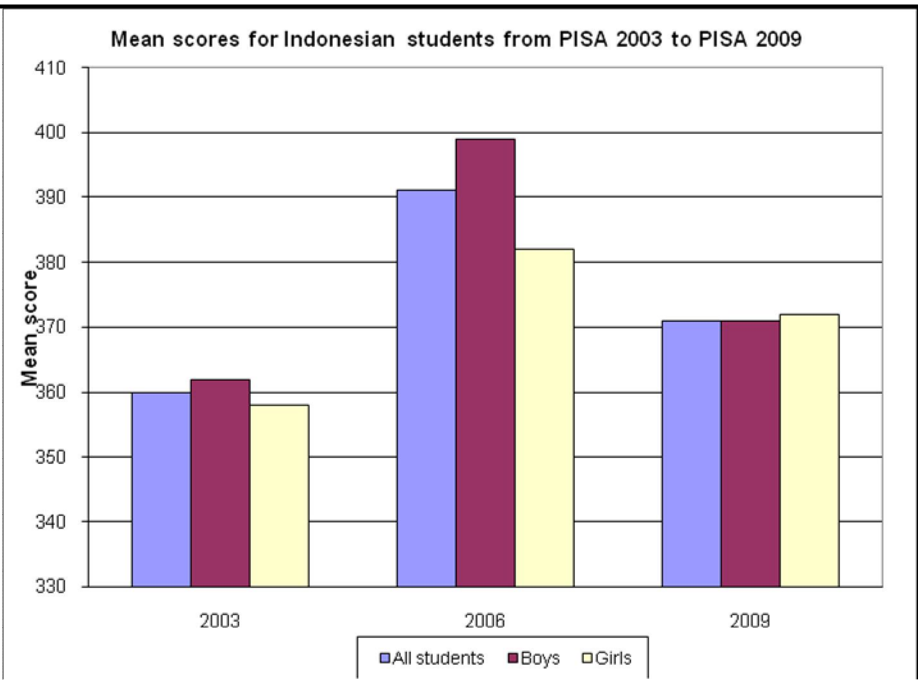


Figure 3. Mean mathematics scores of Indonesian boys and girls from PISA 2003 to PISA 2009 [Data from OECD 2010a, Vol. I, Table I.3.3, p. 224; OECD 2007, Vol. 2, Table 6.2c, p. 230; OECD 2004, Table 2.5c, p. 356].

School Climate

Information about many aspects of school climate and the learning environments is available from the PISA 2009 student and school questionnaires. Two examples are given here. The first is from the student questionnaire, where students respond to

Likert items on their relationships with teachers. Some sample results are given in Table 9, for responses to the following five items:

Item A I get along well with most of my teachers.

Item B Most of my teachers are interested in my well-being.

Item C Most of my teachers really listen to what I have to say.

Item D If I need extra help, I will receive it from my teachers.

Item E Most of my teachers treat me fairly.

The questionnaire data show that Indonesian students report very favourable views of teacher-student relations, being above the OECD average on nearly all measures. The negative responses from Japanese students have been of concern to Japanese educators for some years.

Table 9. *Percentage of students responding 'agree' or 'strongly agree' to five items* [From OECD 2010a, Vol. IV, Figure IV.4.1 p. 89]

Country	Item A	Item B	Item C	Item D	Item E
Indonesia	93	82	63	85	91
OECD average	**85**	**66**	**67**	**79**	**79**
Australia	85	78	71	84	85
Finland	87	49	63	84	80
Hong Kong	89	71	67	89	82
Japan	73	28	63	64	74
Thailand	87	77	82	83	87

The second example is from the school questionnaire. Principals respond to Likert items on many aspects of their schools, including giving their views on how student behaviour in the school affects learning. The data in Table 10 show that in comparison to the selected countries, Indonesian principals are comfortable with these aspects of student behaviour in their schools.

Item G Student absenteeism

Item H Disruption of classes by students

Item I Students skipping classes

Item J Students lacking respect for teachers

Item K Student use of alcohol or illegal drugs

Item L Students intimidating or bullying other students

Table 10. *Percentage of students in schools whose principals reported that the phenomena hindered the learning of students 'not at all' or 'very little'* [From OECD 2010a, Vol. IV, Figure IV.4.4, p. 95]

Country	Item G	Item H	Item I	Item J	Item K	Item L
Indonesia	67	92	83	85	98	94
OECD average	**52**	**60**	**67**	**76**	**91**	**86**
Australia	52	69	77	77	96	81
Finland	27	38	57	67	96	71
Hong Kong-China	83	83	90	84	98	92
Japan	67	91	89	76	98	93
Thailand	39	72	62	87	88	92

What Causes Success on PISA?

Comparisons between countries reveal a complex set of factors that are associated with high scores: there is no magic recipe for success. Finland's success in PISA has been consistent from the beginning. It has always scored very highly (and often best) in reading, mathematics and science. This success has resulted in a great deal of interest in its educational system. Finland's success in PISA is often attributed to the emphasis that their education system places on teacher training to guarantee high-standard instruction. During a conference in March 2005, aimed at educating other OECD countries on the reasons for Finnish success in PISA, Arvo Jäppinen, the top civil servant at the Ministry of Education, explained that the main reason for Finland's results was "Teachers, teachers, and teachers!" (Jäppinen, 2005). In a similar way, the earlier success of Singapore and Japan in TIMSS mathematics created a great deal of interest in their teaching methods amongst researchers, governments and teachers around the world. Japanese lesson study as a method of professional development has become popular and the sale of Singapore's textbooks in the United States flourishes.

It seems that each high performing country explains its success in international assessments in a different way: Singapore refers to careful structuring of school and curriculum. Japan highlights carefully constructed lessons and its culture of lesson study. Finland points to teacher quality. Hong Kong-China points to a combination of strong procedural work, depth in the treatment of mathematics and the Confucian heritage. Netherlands (one of the best European performers) often cites its textbooks and curriculum. We can all learn something from all of these, but these varied voices also highlight the fact that success can be achieved in many different ways, and that the path to improvement will be different in different countries.

Achievement Across Mathematics Content Areas

As noted above, from 2000 to 2009, PISA results were reported according to four 'overarching ideas' (OECD 2009c, pp. 83–122). Figure 4 shows the results for Indonesian boys and girls. The OECD average is about 500 for each overarching idea. Indonesian students performed better on the uncertainty items and less well on the change and relationships items. Indonesian boys tended to perform better than girls on space and shape items, whereas Indonesian girls performed slightly better than boys on uncertainty items. A further analysis at the question level by hierarchical cluster analysis showed that the patterns of success on items for Indonesian students was closest to the responses of students from Tunisia, Japan and Korea (OECD 2009a, p. 123). In common with Mexico and Brazil, questions presented in a personal context were relatively easier for students in Indonesia than problems presented in other contexts (for example, occupational, scientific). (OECD 2009a, p. 136) Other than this, there was no systematic statistically significant effect of context of questions on student performance.

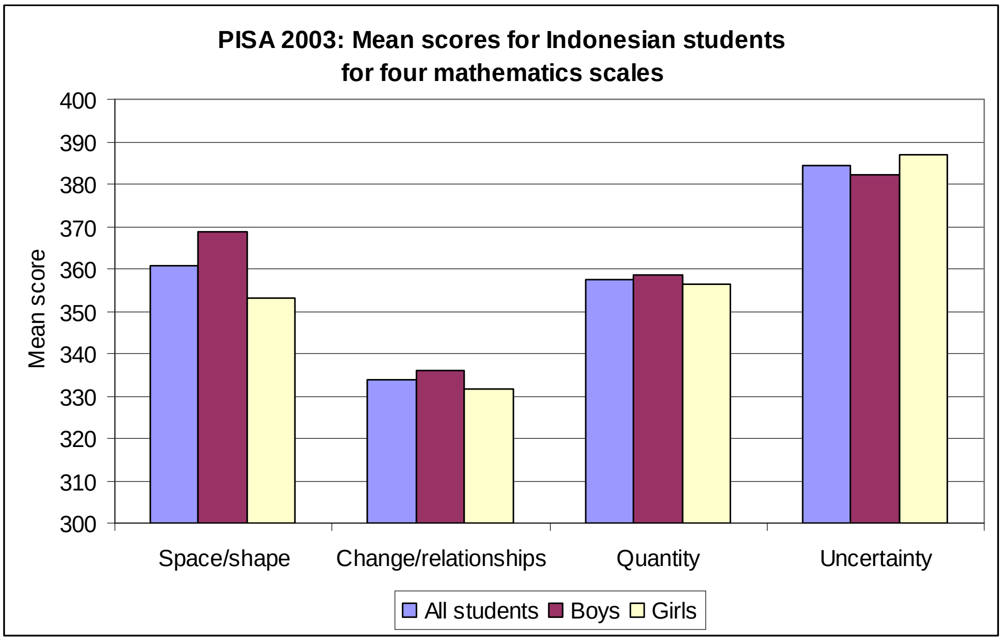


Figure 4. Mean scores on four mathematics scales for Indonesian students for PISA 2003 [Data from OECD 2004, Tables 2.1c, 2.2c, 2.3c, 2.4c].

A separate analysis grouped items into five traditional topics. This demonstrated that PISA 2003 Algebra and Measurement questions were significantly more difficult for students than Number, Geometry and Data. Table 11 shows the mean difficulty index for these topic groupings. Each overall country mean is set to 0, so this table shows the relative difficulty of topics within countries, but not between countries. Figure 5 shows the means and standard deviations for the five traditional topics for Indonesian students.

Table 11. *PISA 2003: Relative mean difficulty of items in PISA 2003 by five traditional topics. (Higher score is greater difficulty for items)* [From OECD 2009b, p. 236]

Country	Algebra (7 items)	Data (26 items)	Geometry (12 items)	Measurement (8 items)	Number (32 items)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Indonesia	0.59 (1.82)	-0.03 (1.15)	-0.31 (1.12)	1.01 (0.99)	-0.24 (1.29)
Australia	0.94 (1.39)	-0.35 (1.24)	-0.15 (1.18)	0.95 (0.94)	-0.10 (1.06)
Finland	1.03 (1.31)	-0.28 (1.20)	-0.08 (1.13)	1.04 (0.89)	-0.23 (1.20)
HK-China	0.51 (1.28)	-0.11 (0.99)	-0.26 (1.25)	0.82 (0.82)	-0.13 (1.20)
Japan	0.69 (1.29)	-0.03 (1.24)	-0.40 (1.30)	0.82 (0.84)	-0.19 (1.42)
Thailand	1.04 (1.40)	-0.16 (1.26)	-0.36 (1.13)	1.08 (1.22)	-0.23 (1.24)

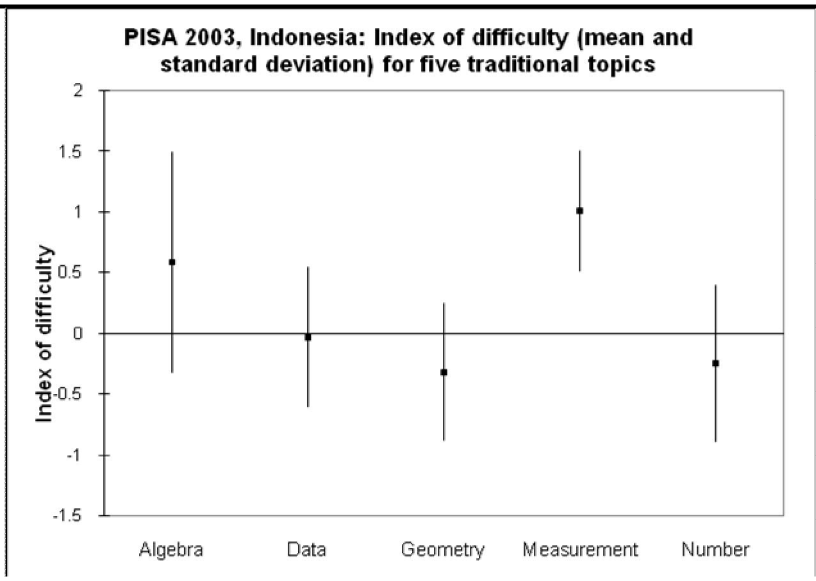


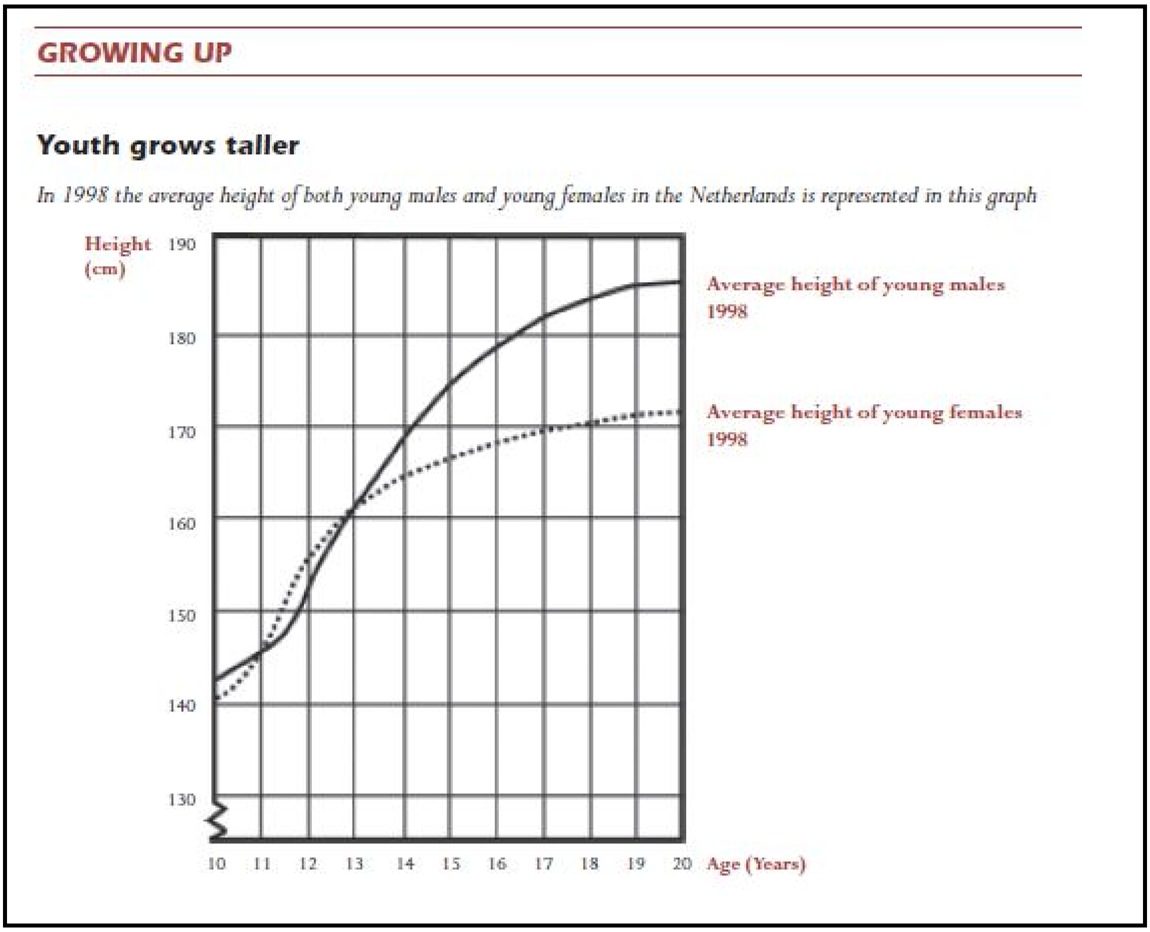
Figure 5. Relative mean difficulty (and standard deviation) of five groups of items for Indonesian students in PISA 2003 [Data from OECD 2009a, p. 236].

Sample PISA Items

A complete set of results is available from the on-line data service accessed through the 'MyPISA' website and all publicly released items can be found in *PISA: Take the test* (OECD 2009b). In this paper, we include some comments on just two sample items. The descriptions of the questions and the data for the responses of Indonesian students are taken from *Learning mathematics for life: A Perspective from PISA* (OECD 2009a).

MATHEMATICS UNIT 6: Growing up

Growing up (Figure 6) presents students with graphs showing the relationships between age in years and average height in centimetres for young males and young females. Question 1 asks students to read a statement then to identify and carry out a simple calculation. Additional information from the graph is not required. Question 2 asks students to compare the two line graphs to identify the ages when females are taller than males. Question 3 asks students to explain how the shape of the line graph reflects changes in the growth rate.



Question 1: GROWING UP

Since 1980 the average height of 20-year-old females has increased by 2.3 cm, to 170.6 cm.
What was the average height of a 20-year-old female in 1980?

Answer: ………………………………………… cm

Question 2: GROWING UP

According to this graph, on average, during which period in their life are females taller than males of the same age?

……………………………………………………………………………………………………

Question 3: GROWING UP

Explain how the graph shows that on average the growth rate for girls slows down after 12 years of age.

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Figure 6. Unit: *Growing up* [From OECD 2009a, pp. 50, 52, 90].

Question 1 illustrates Level 2 in PISA 2003 and has a difficulty of 477 PISA score points. On average across OECD countries, 67% of students across the OECD and 19% of Indonesian students were correct (OECD 2009a, Table 3.1 p. 47; p.51; (OECD 2009a, Figure A1.6).

Question 2 illustrates two different levels of proficiency depending on whether students gave a fully or partially correct answer. Here, a partially correct answer scored illustrates exactly the boundary between Level 1 and Level 2 with a difficulty of 420 PISA score points. A fully correct answer illustrates Level 3 with a difficulty of 525 score points. The percentage of students giving partially or fully correct solutions was 69% (OECD) and 39% (Indonesia) whilst the percentage with fully correct answers was 28% (OECD) and 12% (Indonesia) (OECD 2009a, Table 3.2, p. 63; Figure A1.7).

For full credit, a response to question 3 should refer to the change of the gradient of the graph for females. This can be done by explicitly discussing the steepness of the curve of the graph or implicitly using a measure of numerical growth before and after 12 years of age. Question 3 illustrates Level 4 in PISA 2003 mathematics with a difficulty of 574 PISA score points. In the OECD, 45% of students answered this question correctly compared with 11% in Indonesia (OECD 2009a, Table 3.2, p. 63; Figure A1.22).

Figure 7 shows how Indonesian students responded to *Growing up* Questions 1, 2 and 3. The percentages of students answering each question correctly follow the described difficulty levels, with students finding the Level 1/Level 2 question 2 easiest and the Level 4 question 3 most difficult.

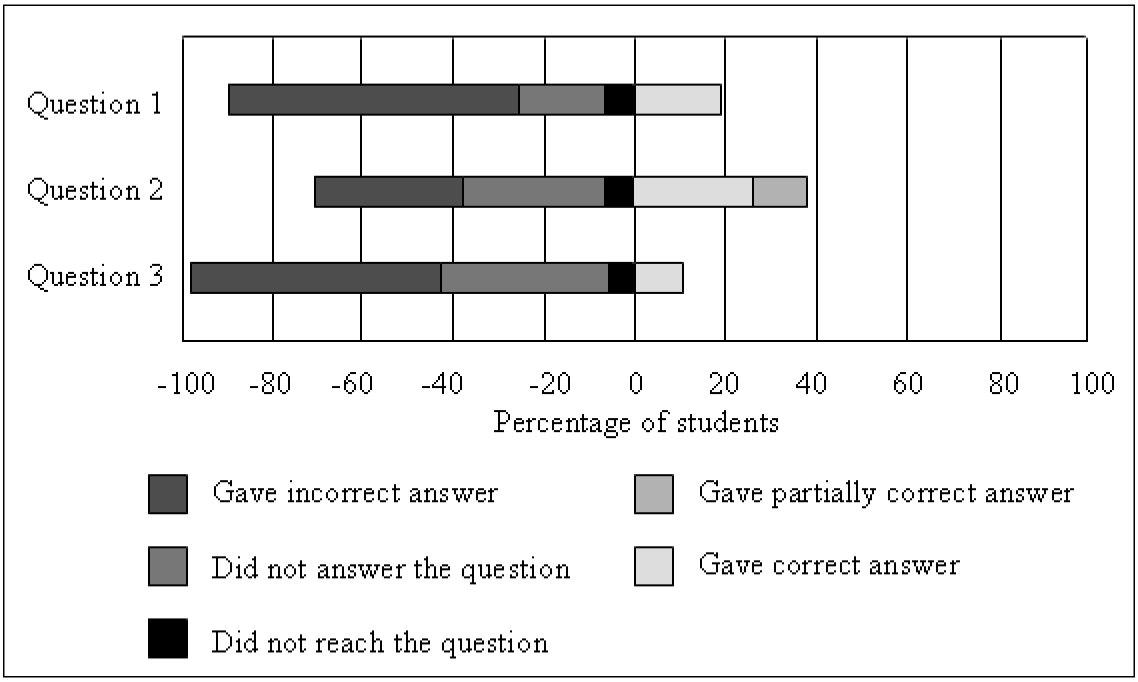


Figure 7. How Indonesian students responded to Questions 1, 2 and 3 of the unit *Growing up* [Data from OECD 2009a, Figure A1.6, p. 205; Figure A.1.7, p. 206; Figure A.1.22, p. 221].

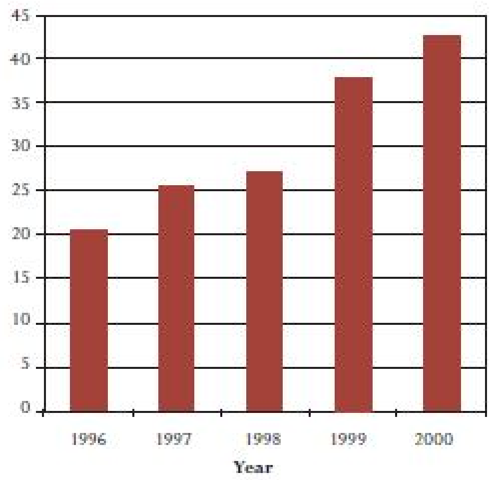
MATHEMATICS Unit 13: Exports

The unit *Exports* (Figure 8) presents students with a column graph and a pie chart. Students must decide which of the two graphs is relevant to each question and must locate the correct information in that graph.

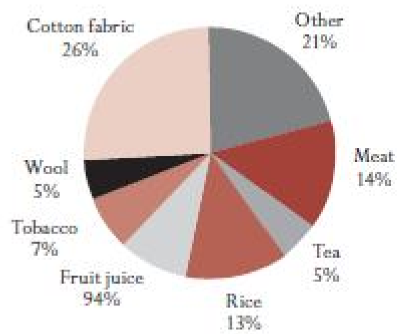
EXPORTS

The graphics below show information about exports from Zedland, a country that uses zeds as its currency.

Total annual exports from Zedland in millions of zeds, 1996-2000



Distribution of exports from Zedland in 2000



Question 1: EXPORTS

What was the total value (in millions of zeds) of exports from Zedland in 1998?

Answer: ....

Question 2: EXPORTS

What was the value of fruit juice exported from Zedland in 2000?

A 1.8 million zeds.
B 2.3 million zeds.
C 2.4 million zeds.
D 3.4 million zeds.
E 3.8 million zeds.

Figure 8. Unit: *Exports* [From OECD 2009a, pp. 169, 170].

Question 1 illustrates Level 2, with a difficulty of 427 PISA score points. This was answered correctly by 70% of Indonesian students and 79% across the OECD. (OECD 2009a, p. 55). This contrasts with the overall results for Indonesia, which showed that almost 70% of Indonesian students were below Level 2 over all topics. Question 2, which illustrates Level 4 and has difficulty of 565 PISA score points was answered correctly by 48% of OECD students and 30% of Indonesian students (OECD 2009a, p. 86). Figure 9 shows the various responses by Indonesian students.

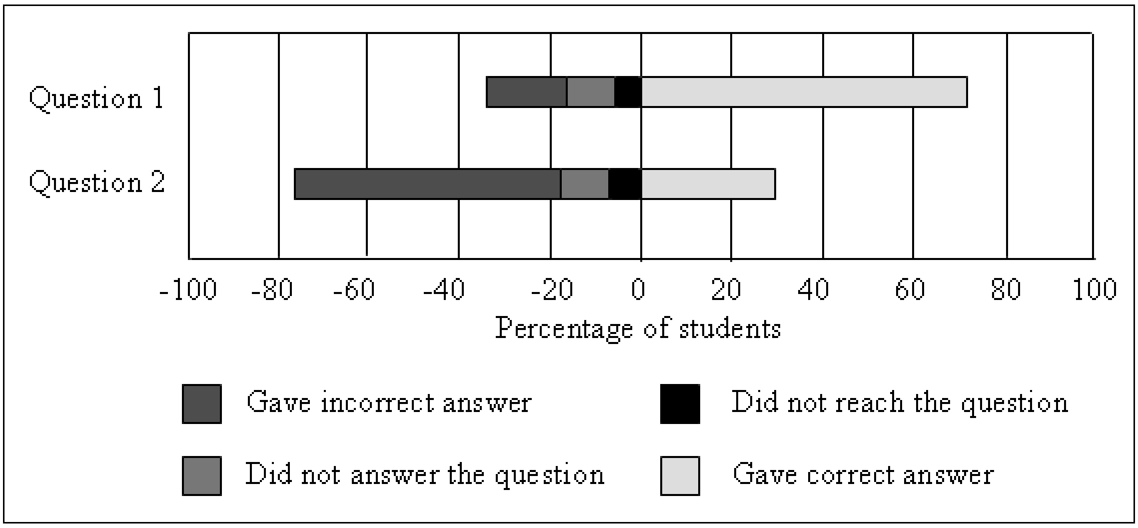


Figure 9. How Indonesian students responded to Questions 1 and 2 of the unit *Exports* [Data from OECD 2009a, Figure A1.3, p. 202; Figure A.1.20, p. 219].

The Future

This paper has aimed to provide an introduction to the PISA program and to give the flavour of some of its findings. Through the numerous primary and secondary analyses of data that are now publicly available, PISA provides a very substantial body of information about education in mathematics. This paper has only been able to show a few examples.

There are several innovations for PISA 2012 (OECD 2010b). First the definition of mathematical literacy is being revised to clarify the construct. An important refinement is to make it clearer that mathematical literacy is not intended to be a low level ability based on basic knowledge and skills, but something that individuals possess and require to various degrees. There will also be some simplification and clarification of the names of the various dimensions of the framework and a stronger indication of the mathematical content that might be useful in PISA items, although there is no intention to systematically assess any syllabus.

The impact of computer technology on mathematical literacy is also receiving more attention, and as noted above, an optional computer-based assessment will be included in PISA 2012. The new PISA definition of mathematical literacy will recognise the important role of information technology by noting that more mathematically literate individuals are better able to use mathematics and mathematical tools to make well-founded judgements and decisions. Working with electronic technology, whether packaged as calculators, computers or special purpose machines, is now an essential component of doing and using mathematics in developed countries and will increasingly impact on the lives of citizens in all countries through the time spans of the next cycles of PISA. The impact of computer technology on the ways in which individuals use mathematics, and consequently should learn it, has long been discussed, and continues to evolve. With the advent of four function calculators, the relative importance of methods of calculation for personal and occupational use changed. Pencil and paper algorithms diminished in importance, being gradually replaced by mental computation and estimation wherever appropriate and backed up by computer/calculator use. The use of calculators has been permitted in all PISA mathematics surveys, where this is consistent with the policy of the participating economy. The intention has not been to test calculator use of itself, or facility with any particular calculator capability, but to assist with calculation, as is normally done when individuals use mathematics.

Additionally, we live increasingly in a society “awash in numbers” (Steen, 2001, p. 1) and “drenched in data” (Steen, 1999, p. 9) where “computers meticulously and relentlessly note details about the world around them and carefully record these details. As a result, they create data in increasing amounts every time a purchase is made, a poll is taken, a disease is diagnosed, or a satellite passes over a section of terrain.” (Orrill, 2001, p. xvi) After analysing the mathematical literacy required in industry and business to respond to the new data-rich environment, Hoyles, Wolf, Molyneux-Hodgson and Kent (2002, p. 3) noted that for employees at all levels in the workplace there is “an inter-dependency of mathematical literacy and the use of IT”. Full participation in society and in the workplace in this information-rich world therefore requires an extended mathematical literacy. The optional computer-based assessment in 2012 will be a first step towards assessing this.

PISA is used by governments to monitor the performance of their educational systems. It can also describe characteristics of the educational system, including those which may impact on whether a society is harnessing the talents of all of its people. Through operationalising the construct of mathematical literacy, PISA has given voice to a vision of education that prepares all future citizens for living productive and satisfying lives. It is up to mathematics education specialists in each country to promote curriculum, teaching and assessment that make this a reality.

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