Australia's participation in international studies: Reflections on what the results tell us about Australian mathematics and science education

Introduction

In 2002 and 2003, data were collected from students around the world for two major international studies – for the IEA *Trends in International Mathematics and Science Study* (TIMSS) and for the OECD *Programme for International Student Assessment* (PISA). In early December 2004, the results of both of these studies were released, providing us with up-to-date evidence about how levels of school achievement in Australia compare with international standards, particularly in mathematics and science.

TIMSS 2002 continues Australia's participation in international studies of mathematics and science going back to the 1960s, and is the third major study to have incorporated mathematics and science into one assessment. Results from the Third International Mathematics and Science Study, conducted in 1994 in Australia, are now able to be compared with results on a similar assessment eight years later. Link items have been retained throughout these eight years so that scores can be scaled to be relevant to prior assessments.

PISA is an initiative of the Organisation for Economic Co-operation and Development (OECD), with the first cycle of PISA taking place in 2000 and there after every three years. There are three main foci (domains) for PISA: reading literacy, mathematical literacy and scientific literacy, and one domain is the major focus in each cycle of PISA, with the other two as minor areas of assessment. Common items are included in each round of assessment for each of the three domains so that change between cycles can be examined.

More than 40 countries participated in TIMSS 2002 and PISA 2003, however not the same countries. All OECD countries participated in PISA, as well as 11 non-OECD or partner countries, which included the Russian Federation, Brazil, Uruguay, Indonesia and Thailand. Thirteen of the thirty OECD countries also participated in TIMSS at Year 8 level, (nine at Year 4 level), as did the Russian Federation, Indonesia and Malaysia, and a number of African and Middle Eastern countries. The United Kingdom as a whole participated in PISA, while England and Scotland participated individually in TIMSS. To participate in TIMSS 2002, a country had to participate at Year 8; however participation at Year 4 was optional. The effect of this is that many more countries participated at Year 8 level than at Year 4 level.

There are two differences between PISA and TIMSS which are important to bear in mind when examining and comparing the results. Firstly, PISA is an age-based sample, whilst TIMSS is a grade-based sample. In Australia both of these have particular repercussions because of state policies with regard to school starting age and the year in which secondary school starts. PISA samples 15-year-old students, whilst TIMSS samples Year 4 and Year 8 students. This means that students in PISA can be spread over two or three year levels, while the ages of students in TIMSS can vary by two or three years.

Secondly the focus of each study is different. The research model for TIMSS is embedded in the curriculum – examining the *intended curriculum,* which is the curriculum as specified at the national or system level, the *implemented curriculum*, which is the curriculum as interpreted and delivered by classroom teachers, and the *attained curriculum,* which is that part of the curriculum that is learnt by students, as demonstrated by their attitudes and achievements. Thus TIMSS starts with curriculum documents from all participating countries and devises an assessment that covers the core content of all participants. Research questions of interest to TIMSS researchers might include: "What are mathematics and science students around the world expected to learn?"; "What opportunities are provided for students to learn mathematics and science?"; "What mathematics and science concepts, processes and attitudes have students learned?"; or "What factors are linked to students' learning?". In contrast, the focus of PISA is on *literacy*. PISA uses the term 'literacy' to encompass a broad range of competencies relevant to coping with adult life in today's rapidly changing societies. The goal of PISA is to measure competencies that will equip students to participate productively and adaptively in their life beyond school education. Therefore, the PISA assessment focuses on young people's ability to apply their knowledge and skills to real-life problems and situations. Mathematical literacy is defined as "an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen" (OECD, 2003, p. 24). Similarly scientific literacy is defined as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD, 2003, p. 133).

In Australia, more than 12,000 15-year-olds participated in PISA, and around 5,000 participated in TIMSS at each of Year 4 and Year 8. These students were drawn from all states and territories, and included students from government, Catholic and independent schools in proportion to their enrolments. In each study the sample of schools was randomly drawn and smaller states as well as Indigenous students were oversampled so that reliable estimates could be obtained. For TIMSS, a class was then randomly drawn from the appropriate year level, and all students in that class invited to participate. For PISA, a random sample of 15-year-old students was drawn from the pool of eligible students.

Rigorous sampling requirements were necessary for both studies to ensure unbiased data. For data from a country to be eligible for inclusion in TIMSS, the minimum participation rates were 85 per cent of first selected schools and 85 per cent of sampled students. Australia achieved the required response rates for Year 8 students, but for Year 4 the participation rate was met only after replacement schools were included. Nevertheless, because of the manner in which replacement schools were selected, the Year 4 sample is considered to be representative of the Year 4 population. Similarly, for data from a country to be eligible for inclusion in PISA, the OECD required a response rate of at least 85 per cent of first selected schools, and 80 per cent of sampled students. Australia achieved the sample requirements for PISA. In both studies, there were countries which failed to meet sampling requirements; England in particular failed to achieve the sample participation rates for either the Year 8 TIMSS sample or the PISA sample. This is a great concern both to policy makers and to the funding bodies for both studies, and underlines the importance of teachers being well-informed and supportive of a country's participation in international studies. If we are to be part of a global economy, it is vital that we are able to assess how well our education systems are doing in preparing the young people of today for participation in these economies.

The data obtained from these studies provide a rich source of information about overall levels of achievement. As well, the data from both studies allow us to provide details about the achievement levels of males and females, of students in each state and territory, of indigenous students, those with a language background other than English, those living in urban, regional and rural areas, and those from differing levels of socioeconomic background. We are also able to examine links between attitudes and achievement, and the impact of school resources on achievement. While it is commonly the average performance that is assessed, means can mask significant variation in individuals, classes or schools. Countries aim not only to encourage high performance but also to minimise internal disparities in performance, so it is important that we also examine the proportion of students at the lower end of mathematics achievement.

How did Australian students perform in TIMSS and PISA?

In a nutshell, Australia's performance at both year levels in TIMSS mathematics has remained unchanged over the eight years since the first TIMSS assessment. Australia's score is also not significantly different to the international mean at Year 4, but it is significantly higher than the international mean at Year 8. In TIMSS 1994, Australia's score at both year levels was significantly higher than the international mean, and at both year levels there were only a handful of countries which out-performed our students. In TIMSS 2002, countries which out-performed Australia included Asian countries such as Singapore, Japan, Chinese Taipei, and Hong Kong-China, as well as European countries such as Belgium (Flemish), the Netherlands and Hungary. At Year 8 level, the performance of other countries has improved to the extent that half of the countries out-performed by Australia in mathematics in TIMSS 1994 performed at a similar level or higher than Australia in mathematics in TIMSS 2002.

In TIMSS science, students at both year levels achieved at a rate higher than the international mean, however again the performance of Australian year 4 students has remained the same since TIMSS 1994. Countries such as Singapore, England and the United States, which scored at a similar level to Australia in TIMSS 1994, have improved their scores to the extent that in TIMSS 2002 their average scores were significantly higher than those of Australia. The performance of year 8 students in TIMSS science has, however, significantly increased over these eight years, and Australian students are now out-performing students in some countries (Belgium (Flemish), Russian Federation) which were performing at a similar level to Australia in TIMSS 1994.

Australia's performance was higher than the OECD mean in PISA 2003 mathematical literacy – this mean only includes the scores from OECD countries. This score was similar to that of PISA 2000, in which mathematics was a minor domain, and was surpassed in PISA 2003 by four countries: Hong Kong-China, Finland, Korea and the Netherlands. In scientific literacy, Australia's score was statistically similar to that in PISA 2000, and was only surpassed by Finland, Japan, and Korea.

Performance against benchmarks

Another way of examining achievement that in many ways provides a more complete picture for a country is to look at performance against particular benchmarks. TIMSS defines four benchmarks internationally in both mathematics and science, ranging from the lowest level, in which students were able to demonstrate some level of rudimentary mathematics or scientific knowledge, through to the advanced benchmark, where students demonstrated more sophisticated skills in mathematics or science; applying knowledge and understanding in a particular area to a variety of complex situations. PISA defines six proficiency levels in mathematics; the highest and lowest are similar to those in TIMSS but the middle levels are defined more explicitly. PISA also defines *proficiency not yet at Level 1*; students performing at this level were unable to utilise mathematical skills in a given situation as required by the easiest PISA task. These students, it is argued, will have difficulty participating fully in society beyond school due to their lack of skills.

Whilst it is important that a country achieves a high proportion of students at the highest benchmark or proficiency level, it is perhaps even more important that as many students as possible are able to achieve the lowest levels. For PISA, mastery of at least proficiency level 2 is perceived as the baseline for mathematical literacy at this level of education. For TIMSS, while no such level has been defined, it could be argued that students who are achieving at the low or not yet achieving the low benchmark are going to have difficulty in later life applying mathematical concepts. In the following graphs, Figure 1 shows achievement at each of the benchmarks for TIMSS 2002 mathematics and science, and Figure 2 shows achievement at each proficiency level for mathematical literacy in PISA 2003. Similar figures cannot be developed as yet for scientific literacy as it has been a minor domain in both PISA assessments and so proficiency levels have not as yet been described.

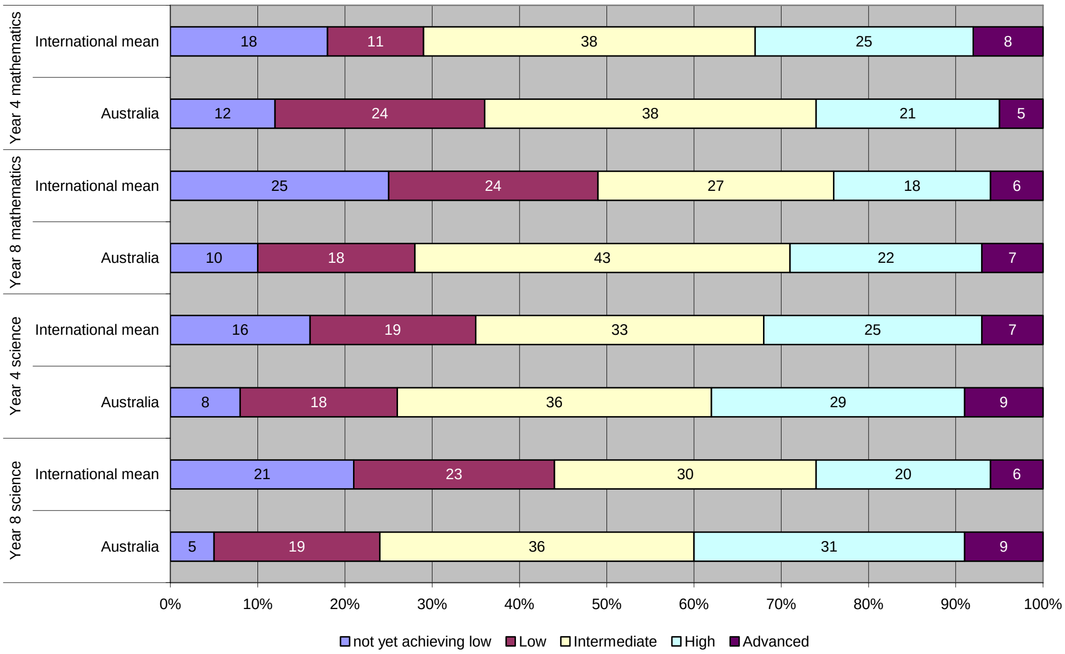

Figure 1. Achievement of benchmarks in TIMSS 2002 mathematics and science

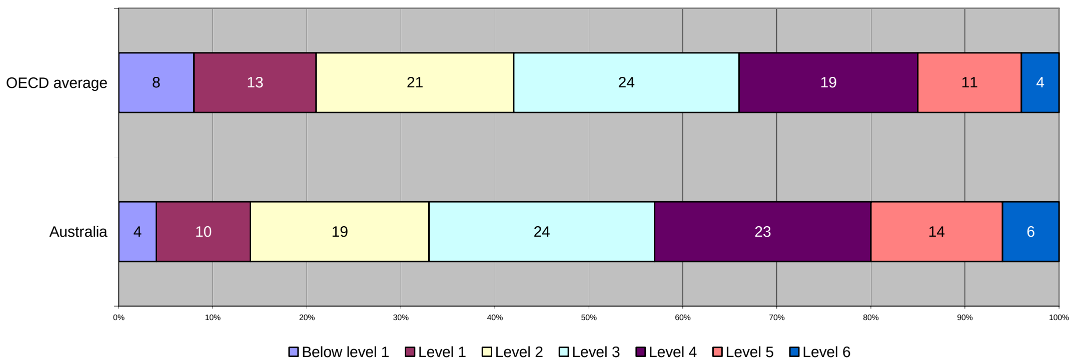

Figure 2. Achievement of proficiency levels in PISA 2003 mathematics

The data for both studies tell a disconcerting story. In TIMSS, around one-quarter of students in year 4 and year 8, in both mathematics and science, are achieving below the intermediate level, either not yet achieving or achieving only the low benchmark. In PISA, one-third of students are achieving at Level 2 or below in mathematics. In contrast, less than one in ten were achieving at the highest proficiency level.

Conclusions

PISA and TIMSS provide information about different aspects of students' mathematics and science learning. While students in some countries - such as Hong Kong-China and Korea— perform very well in both these areas, students in some other countries perform better in one area than the other.

In Australia, students perform better (on average) in applying general mathematical and scientific principles and skills to everyday problems than in recalling and using curriculum-based factual and procedural knowledge. However the proportions that could be thought to be ‘at-risk’ were roughly similar in each study.

An obvious question that follows from these observations is whether Australian schools are placing sufficient emphasis on the teaching of factual and procedural knowledge in mathematics and science, particularly at Year 4. While 73% of Year 4 students in Singapore reach the high international mathematics benchmark, only 26% of Australian students reach this benchmark. Also, relative to other countries, Australian Year 4 students now perform less well in school mathematics and science than they did almost a decade ago.

During the 1990s, considerable effort went into the reform of curricula for the primary and middle years of schooling in Australia, resulting in new state curriculum and standards frameworks. In the same period, education systems introduced system-wide testing programs to monitor student and school achievement. It is not clear that these efforts have improved levels of mathematics and science performance in Australian primary schools. If Australia is to lift its performance in TIMSS over the next decade, then greater attention will need to be given to the teaching of basic factual and procedural knowledge and the development of teachers’ confidence and competence in teaching primary school mathematics and science. The focus of the past decade on *what* is taught (the curriculum) needs to be accompanied by a greater focus on *how* subject matter is taught (research-based pedagogy). As well, testing programs for accountability and monitoring need to be complemented by assessments that are capable of diagnosing individuals’ learning difficulties and providing guidance to classroom teaching and learning.

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