DOCUMENT RESUME

ED 421 495 TM 028 454

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TITLE	Third International Mathematics and Science Study. Performance Assessment: Strengths and Weaknesses of Students in England.
INSTITUTION	National Foundation for Educational Research, Slough (England).
PUB DATE	1998-04-00
NOTE	39p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Diego, CA, April 13-17, 1998).
PUB TYPE	Reports - Evaluative (142) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	British National Curriculum; Comparative Analysis; Cross Cultural Studies; Foreign Countries; *International Studies; *Junior High School Students; Junior High Schools; Mathematics Achievement; *Performance Based Assessment; Performance Factors; Science Instruction; *Test Results
IDENTIFIERS	*England; *Third International Mathematics and Science Study

ABSTRACT

England was 1 of more than 40 countries that took part in the Third International Mathematics and Science Study (TIMSS) survey of 13-year-olds. This paper presents background information on the TIMSS and the performance assessment element of the study. It also describes how the written test and the practical task components relate to the National Curriculum orders for mathematics and science in England, and it examines the results for students in England on the performance assessment, with reference to their strengths and weaknesses and examples of students' responses. In England, 450 Year-9 students (equivalent to the international eighth grade) from 50 schools were involved in the performance assessment as part of a world-wide sample of about 15,000 students. In all, 12 different performance tasks were used: 5 focusing on mathematics, 5 focusing on science, and 2 on elements of both. The performance of students in England was above the international means for mathematics, science, and overall performance on the 12 tasks. Of the 19 countries represented in the international TIMSS report, English students ranked seventh on the mathematics tasks, second on the science tasks, and second on overall results. In light of the relatively poor performance of English students on the written mathematics tests of the TIMSS, the performance assessment results offer some comfort by indicating that there are areas of mathematics in which English students are doing well. (Contains 4 tables, 12 figures, and 13 references.) (SLD)

Third International Mathematics and Science Study. Performance Assessment: Strengths and Weaknesses of Students in England.

Susan Harris

This paper is prepared for the:
Annual Meeting of the American Educational Research Association in San Diego, CA
April 1998

THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

Performance Assessment: Strengths and weaknesses of students in England

Paper prepared for AERA San Diego, April 1998

Susan Harris

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CONTENTS

TIMSS PERFORMANCE ASSESSMENT:
the strengths and weaknesses of students in England

1. INTRODUCTION

England was one of more than 40 countries that took part in the TIMSS survey of 13-year-olds. This involved the administration of written tests in mathematics and science to a randomly-selected representative sample of students in Years 8 and 9 (equivalent to international grades seven and eight), together with the completion of questionnaires about these subjects by the students, their mathematics and science teachers and headteachers. The Performance Assessment was an additional, optional component to the study which involved a sub-sample of the students that had participated in the main survey in attempting a number of practical tasks in mathematics and science. Approximately half of the 41 countries that participated in the survey of 13-year-olds took part in the Performance Assessment with 13-year-olds; England was one of those countries.

This paper will present background information about TIMSS and the Performance Assessment element of the study; it will also describe how both the written test and practical task components relate to the National Curriculum Orders for mathematics and science in England, and examine the results for students in England on the Performance Assessment, with particular reference to their strengths and weaknesses illustrated by examples of students' responses.

1.1 TIMSS study design

Some summary information about the design and administration of the study as a whole is presented here for background purposes, but readers who seek more detailed information about the aims of the study, its design, and administrative and analytical processes are referred to other national[1] and international reports[2].

England was one of the countries taking part in TIMSS. The study was designed to focus on the teaching and learning of mathematics and science in three target populations:

- upper primary students, aged about nine years (Population 1)
- lower secondary students, aged about 13 years (Population 2)
- upper secondary students, aged about 17/18 years (Population 3).

[1] See Keys *et al.*, 1996a; Keys *et al.*, 1996b; Harris *et al.*, 1997a; Harris *et al.*, 1997b; Keys *et al.*, 1997a and Keys *et al.*, 1997b for national information.

[2] See Beaton *et al.*, 1996a; Beaton *et al.*, 1996b; Martin *et al.*, 1997; Mullis *et al.*, 1997 and Harmon *et al.*, 1997 for international information.

For each population there were two main aspects to the data collection:

- achievement tests in mathematics and science for the students
- questionnaires covering background information and other issues, such as attitudes to these subjects, for students, their mathematics and science teachers and their headteachers.

All countries taking part in TIMSS were required to survey lower secondary students (Population 2) and participation in the surveys of Populations 1 and 3 was optional. England was one of 26 countries that took part in the survey of Population 1 and was one of more than 40 countries that surveyed Population 2.

The assessment of students' achievement in mathematics and science was carried out by means of written tests. The content of the written tests was rotated to provide eight different versions (determined by the International Study Center). Each of the eight versions of the test contained both mathematics and science items. The total testing time for 13-year-olds was 90 minutes, split into two sessions with a short break in-between.

The Performance Assessment was intended to supplement the data collected by means of the written tests. It consisted of a number of specific tasks that allowed students to demonstrate their practical, investigative, recording and analytical skills in mathematics and science in controlled situations. This element of the study was designed for the upper grades tested in Populations 1 and 2 only; participation in the Performance Assessment for Population 1 and/or Population 2 was optional. Twenty-one countries (including England) participated in this aspect of TIMSS with 13-year-old students, i.e. about half of the total number of countries who administered the written tests in mathematics and science to students.

Within England, 450 Year 9 students (equivalent to international eighth grade) from 50 schools were involved in the Performance Assessment. This was part of a worldwide sample of approximately 15,000 students of a similar age in 1,500 schools. More detailed information about the sampling is provided in Appendices III and V to the TIMSS national reports for England (Keys *et al.*, 1996b).

1.2 The context for Performance Assessment

Although cross-national studies have been conducted for more than 30 years by the International Association for the Evaluation of Educational Achievement (IEA), the data collection in mathematics and science studies has been predominantly by means of written achievement tests and questionnaires. Undoubtedly, a consideration in study design has to be the increased cost of administering practical tasks in controlled conditions: to attempt to do this with substantial numbers of students can prove costly. Historically, the numbers of countries that have participated in optional practical components of international mathematics and science studies have been relatively small, possibly reflecting considerations associated with the cost of administration, but also possibly due to less interest in assessing students' practical skills. However, in recent years there has been increased interest in assessing not only students' knowledge and understanding using written tests, but also their practical, investigative, problem-solving and analytical skills by means of 'hands-on' activities. By offering the Performance Assessment as an additional component, TIMSS has become the largest international study to include a practical assessment of students' performance, collecting complementary sets of data that more accurately reflect the range of students' curricular experiences in mathematics and science.

In England a noteworthy predecessor of the TIMSS Performance Assessment was the series of surveys initiated by the Assessment of Performance Unit (APU) which were conducted in England, Wales and Northern Ireland from 1977 to 1990. Surveys in both mathematics and science were carried out with 11- and 15-year-olds, and, additionally, the science team surveyed 13-year-olds. The practical activities utilised in the APU mathematics and science surveys were mostly administered on a one-to-one basis, with a trained assessor presenting the task to the student and recording his/her responses. In some instances science activities were presented as a 'circus' of tasks which students attempted in turn. In the final mathematics survey, in an amended format for the administration, some students were expected to work collaboratively in groups of three. Collectively, the activities were designed to assess students in not only carrying out routine tasks, such as using measuring instruments, but also to identify the strategies they adopted in problem-solving situations and their reasons for choosing particular approaches.

With the introduction of the National Curriculum in 1989 and its associated assessment arrangements, the work of the APU drew to a close, although it is true to say '... some of the materials, particularly practical and oracy assessments, have influenced and extended good practice in their areas' (Foxman *et al.*, 1991). Historically, therefore, in England there had been a tradition of assessing students' practical, problem-solving and investigative skills in mathematics and science prior to the TIMSS survey.

1.3 The Performance Assessment tasks

In total, 12 different tasks were used in the Performance Assessment for Population 2: five focusing on mathematics, five focusing on science, and two with elements of both mathematics and science. (Within the international report, the information relating to students' performance on the two tasks related to both subjects has been included within the main sections relating to mathematics and science respectively, and this approach will also be adopted within this paper.) The time allowed for the completion of tasks was either 15 minutes or 30 minutes. Typically, the 15-minute tasks required routine skills such as constructing tables to record results, and summarising observations, whereas the 30-minute tasks involved skills such as planning and carrying out an investigation, graphing results and drawing conclusions. The times allocated for each of the tasks are shown in Table 1.3.1.

Table 1.3.1: Times allocated to mathematics and science tasks

TASK	NAME	TIME
Mathematics		
M1	*Dice*	15 mins
M2	*Calculator*	15 mins
M3	*Folding and Cutting*	15 mins
M4	*Around the Bend*	30 mins
M5	*Packaging*	30 mins
SM2	*Plasticine*	30 mins
Science		
S1	*Pulse*	15 mins
S2	*Magnets*	15 mins
S3	*Batteries*	15 mins
S4	*Rubber Band*	30 mins
S5	*Solutions*	30 mins
SM1	*Shadows*	30 mins

The 12 tasks were organised to form activities at nine workstations: three of the workstations each presented two 15-minute tasks (one mathematics and one science task), and the remaining six workstations each presented one 30-minute task for students. During the administration, each student visited three different workstations and, depending on the combination of 15- and 30-minute tasks, attempted either three, four or five tasks in a total working time of 90 minutes.

Each task was presented to students in the form of a four-page booklet which provided details of the activity and asked questions related to the task. Most of the students' responses were written in the booklets, although some tasks required additional evidence of work, such as a graphs, scale drawings, nets of 3D shapes and masses of plasticine. Students' marks were based on both their written responses and the additional evidence (such as that mentioned above) which they produced in connection with the tasks.

In summary, the students who attempted the Performance Assessment formed a sub-sample of the Year 9 (international grade 8) students who had already completed written tests and questionnaires in these subjects. The total testing time was 90 minutes for the written tests and a further 90 minutes for the Performance Assessment. There was a rotated test design for both these elements of TIMSS.

1.4 National Curriculum links to TIMSS

A National Curriculum was introduced in England and Wales in 1989. This was notable for specifying *what* students should learn in each subject area, whilst allowing teachers freedom in determining the teaching methods, texts etc. to utilise in teaching the subject matter (i.e. '*how*' to implement the curriculum). The structure and content of the Statutory Orders in mathematics and science have been subject to amendment since their introduction (both subjects were revised in 1991 and in 1995), but remain, in essence:

- **curriculum guidelines:** what should be taught to students in different phases of education (e.g. lower primary: Key Stage 1; upper primary: Key Stage 2; lower secondary: Key Stage 3)
- **assessment criteria:** descriptions of typical performance for different levels of achievement. Descriptions are given for eight different levels, which span early primary school achievement to upper secondary school achievement; a final category after the eighth level is classified as '*exceptional performance*'.

Within the curriculum guidelines, the National Curriculum Orders for mathematics and science have, since their inception, identified two main elements of students' work and achievements in these two subjects:

- knowledge and understanding in each subject (i.e. content)
- process skills related to each subject.

The underlying assumption in the structure of the Orders for mathematics and science is that students will develop appropriate process skills related to each of these subjects by carrying out investigations which are set in the context of work relating to the content-based aspects of the curriculum. For example, the process skills to be developed in science include the formulation of hypotheses, the ability to design and carry out a fair test, which would involve identifying and controlling variables, and the ability to interpret data collected, identify patterns and draw conclusions. Practical activities which would allow students to develop and refine these types of skills would be related to part of the curriculum for which content is specified. For example, as part of their work concerning *Life Processes and Living Things* students would study different organs and systems. They would design and carry out investigations relating to this work, such as investigating how different forms of exercise affect respiration and heart rate.

In essence, the written TIMSS tests had a stronger link to the content-based parts of the National Curriculum Orders for mathematics and science, whereas the Performance Assessment tasks were more representative of the Orders' emphasis on designing and carrying out investigative work in these subjects. Table 1.3.2 shows the links between the different elements of the National Curriculum Order for mathematics and the TIMSS written mathematics tests and practical mathematics tasks; Table 1.3.3 shows similar links for science.

Table 1.3.2: Links between the National Curriculum for mathematics and aspects of TIMSS

Part of National Curriculum Order	TIMSS written tests	TIMSS practical tasks (Performance Assessment)
Ma1: Using and Applying Mathematics	○	●
Ma2: Number and Algebra	●	○
Ma3: Shape, Space and Measures	●	○
Ma4: Handling Data	●	○

Table 1.3.3: Links between the National Curriculum for science and aspects of TIMSS

Part of National Curriculum Order	TIMSS written tests	TIMSS practical tasks (Performance Assessment)
Sc1: Experimental and Investigative Science	○	●
Sc2: Life Processes and Living Things	●	○
Sc3: Materials and their Properties	●	○
Sc4: Physical Processes	●	○

KEY: ● = strong links ○ = some links

The written achievement tests completed by the students that participated in the TIMSS survey collected data about the performance of students in a range of content areas in the two subjects tested (for details of the curriculum frameworks see Robitaille, 1993). In terms of relevance to the National Curriculum Orders for mathematics and science, the content of the written tests is most closely related to those parts of the respective programmes of study concerned with knowledge and understanding of concepts: Ma2, Ma3 and Ma4, and Sc2, Sc3 and Sc4.

The Performance Assessment tasks, because of their practical nature, are more closely related to the process-oriented aspects of the National Curriculum Orders for mathematics and science respectively i.e. Ma1: Using and Applying Mathematics and Sc1: Experimental and Investigative Science. However, just as classroom work on these aspects of the programmes of study has to be set in a context (usually related to part of the content-focused part of the Order) so the Performance Assessment tasks similarly have their practical and investigative activities set in a context related to the content-focused part of the Order. Consequently, although these tasks are predominantly linked with the skills-focused parts of the Orders (Ma1 and Sc1), the context of each one will have links with the content-focused part of the Order.

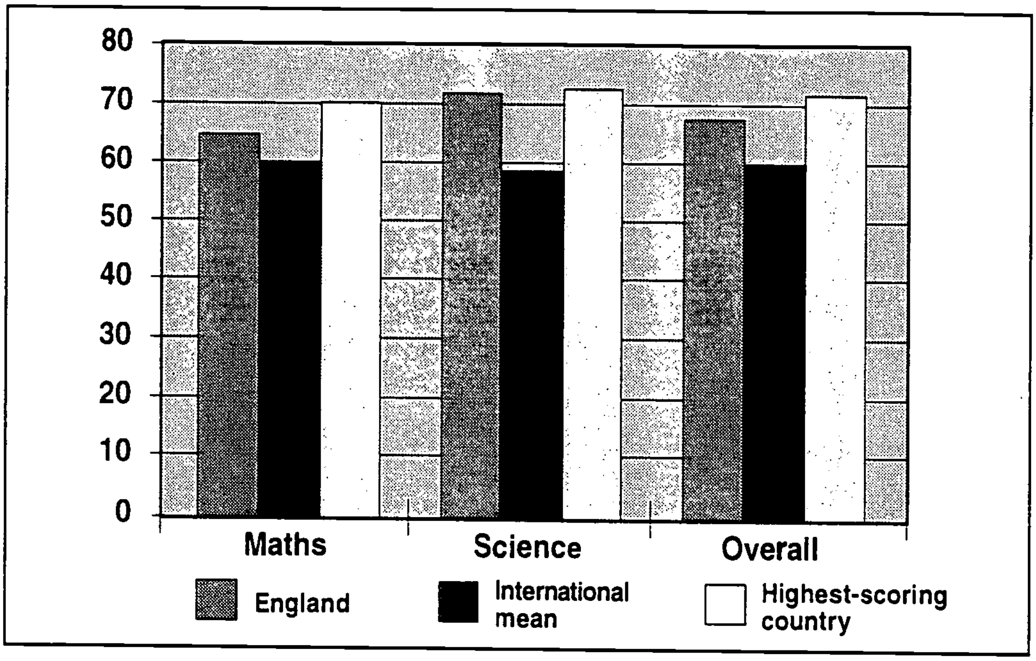
In the same way that the National Curriculum Orders for mathematics and science emphasise both knowledge and understanding of concepts in these subjects *and* experimental and investigative skills, the results for students on the written achievement tests and on the practical tasks complement each other, reflecting both subject knowledge and practical skills. Whilst the results for students in England on either component present an incomplete picture of their performance as compared with that of their counterparts in other participating countries, together, the data collected by both aspects provide the most accurate reflection of the standards achieved by students in the two components which approximate to the two main areas addressed by the National Curriculum Orders for these subjects. Within the rest of this paper, therefore, although the focus of the discussion will be concerned with the results for students in England on the Performance Assessment component of TIMSS, references will be made to students' results on the written tests, and each of the two components should be seen as representing part of the National Curriculum for both mathematics and science respectively.

2. STUDENTS' PERFORMANCE

2.1 Students' overall performance in mathematics and science

Figure 2.1.1 shows the overall performance of students in England on the six mathematics tasks, the six science tasks and on the 12 tasks altogether, together with the international means and the scores of the highest-scoring countries for each of these for comparative purposes.

Figure 2.1.1: Mean percentage scores by subject overall



Source: Table 2.3 (Harmon *et al.*, 1997)

It is evident from Figure 2.1.1 that the performance of students in England was above the international means for mathematics, science and for overall performance on all 12 tasks. In summary, out of the 19 countries[3] whose results are presented in the international report, the position of students in England was

- ranked equal seventh on their results on the six mathematics tasks
- ranked second on their results on the six science tasks
- ranked second on their overall results on all 12 tasks.

It is not possible to make direct comparisons with students' performance on the written tests since approximately twice as many countries participated in the main survey of Population 2 as compared with the number that took part in the Performance Assessment. However, a

[3] The results for two of the countries that administered the Performance Assessment, Hong Kong and Israel, are presented separately from the main tables and figures in the international report (Harmon *et al.*, 1997) due to small samples. Within this paper, therefore, as in the international report, international comparative data will be based on the results of those 19 countries shown in the main tables and figures in the international report.

reasonable interpretation would be that the results on the mathematics tasks were better than on the written tests, and the results on the science tasks were consistent with performance on the written science tests (Keys *et al.*, 1996a: the mean overall mathematics score of Year 9 students in England was significantly *lower* than those of students in about half of the 41 countries that took part in the survey, whereas the mean overall science score for the same students was significantly *lower* than those of students in only four of the participating countries). It should be acknowledged, however, that of the 19 countries whose students achieved significantly higher scores in the written mathematics tests for international grade 8 (equivalent to Year 9 in England), only eight participated in the Performance Assessment.

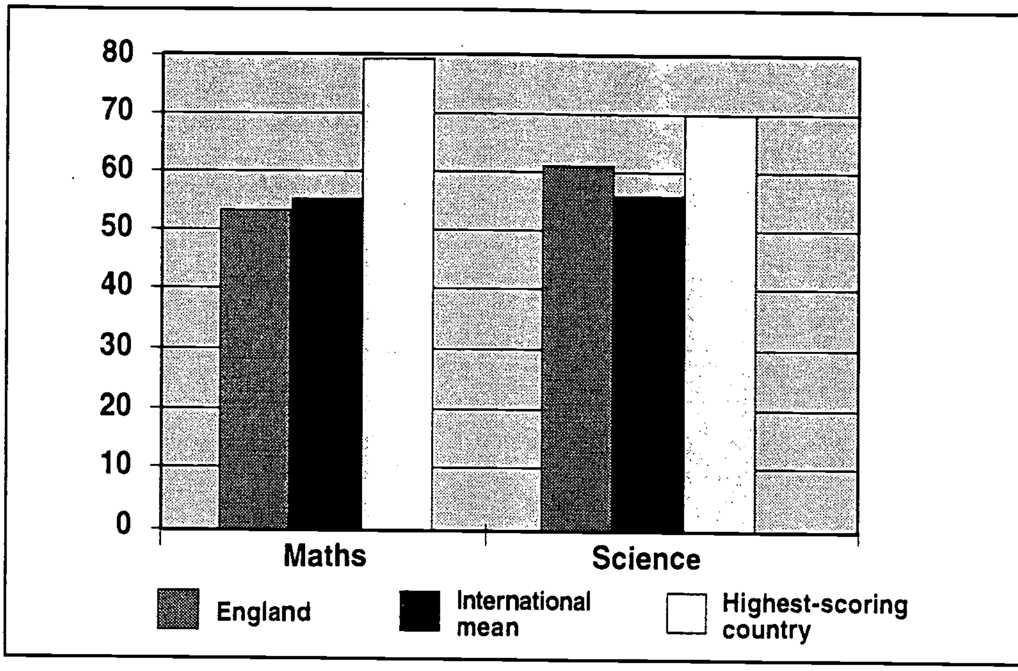
Students in six countries achieved higher mean percentages scores in mathematics than those in England on the Performance Assessment; four of these (Singapore, Sweden, Switzerland and Australia) had also achieved significantly higher results on the written mathematics tests. However, in five of these six countries the difference in performance on the practical tasks was no more than two percentage points; students in Singapore (the highest-scoring country for mathematics) outperformed their counterparts in England by six percentage points in mathematics.

Three of the countries whose students had significantly higher results than those in England on the written mathematics tests achieved slightly lower mean percentage scores on the mathematics tasks (the Netherlands, Canada and the Czech Republic), although these differences amounted to only two percentage points in each case.

In the TIMSS written science tests, students in only four countries (Singapore, the Czech Republic, Japan and Korea) had science results which were significantly higher than those of students in England. Only two of these countries participated in the Performance Assessment: Singapore and the Czech Republic. In the case of the former country, students' results on the Performance Assessment science tasks were only one percentage point above the mean percentage score for students in England; in the case of the latter, students' results on the science tasks were 11 percentage points lower than the mean percentage score for students in England. This difference in performance relative to students in the Czech Republic suggests that there may be different emphases in the science curriculum in these two countries.

Figure 2.1.2 shows the overall results for students in Year 9 (international eighth grade) on the written tests in mathematics and science, together with international data for comparison.

Figure 2.1.2: Mean percentage scores on written tests



Source: Beaton *et al.*, 1996a and Beaton *et al.*, 1996b

However, it is inevitable that the generally favourable results for England in the Performance Assessment fail to show particular strengths and weaknesses in students' performance, simply because when results over several items within each task, and subsequently, several tasks are aggregated to produce a mean percentage score for mathematics/ science/overall performance the extremes of performance, both high and low, are obscured. The rest of this paper will therefore illustrate some of the strengths and weaknesses in the performance of Year 9 students in England on the practical tasks in mathematics and science.

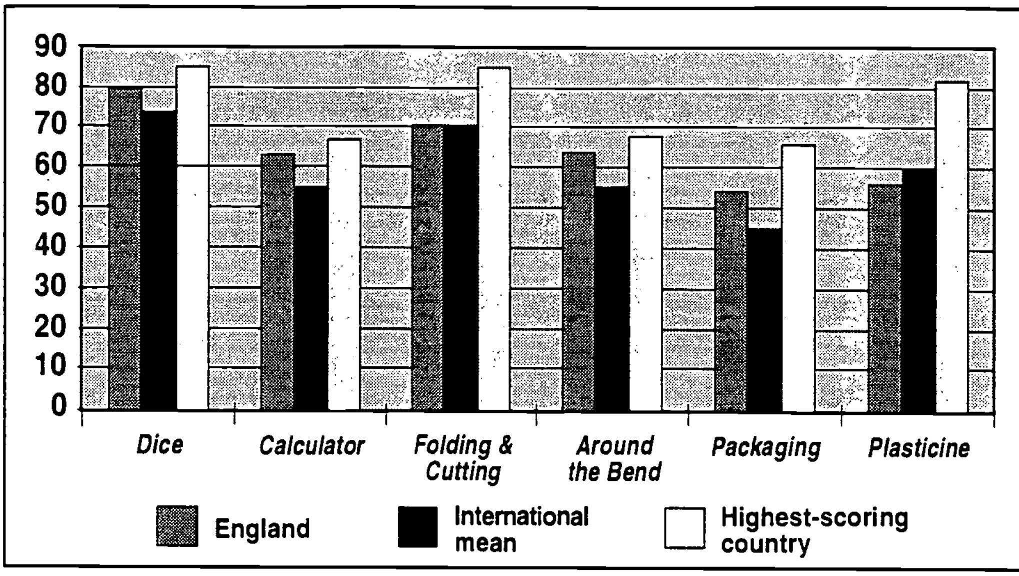
2.2 Results on mathematics tasks

Figure 2.1.1 above has shown the overall performance of students in England on the six mathematics tasks, however, performance was not at a similar level on each one of these tasks. Figure 2.2.1 shows the performance of students in England on each of the mathematics tasks together with the international means and the results for these tasks from the highest-scoring countries[4] for comparative purposes.

As shown in Figure 2.2.1, the results for students in England were equal to or higher than the international mean on five of the six tasks. This is in contrast to the results on the written mathematics tests, in which students mean percentage scores were lower than the international mean for five of the six content areas in the tests.

[4] Students in different countries achieved the highest mean percentage scores for different tasks.

Figure 2.2.1: Performance on the six mathematics tasks

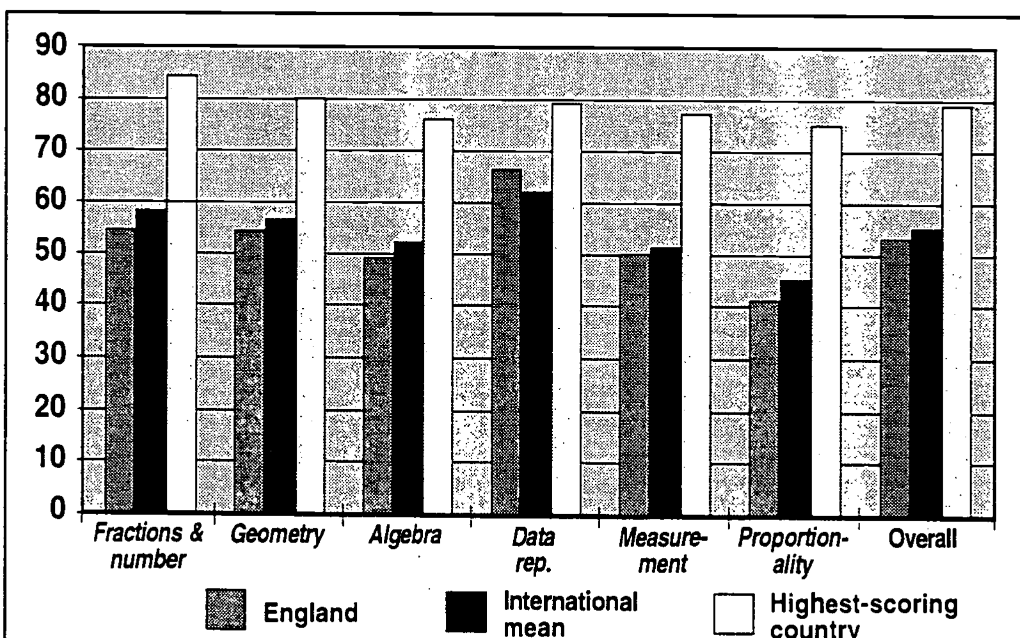


Source: Table 2.1 (Harmon *et al.*, 1997)

It is apparent from Figure 2.2.1 that the poorest results for students in England were on the *Plasticine* task, in which their overall performance (55 per cent) was lower than the international mean (by five percentage points) and 26 percentage points below the mean percentage score achieved by students in the highest-scoring country. In contrast, their results on *Calculator* (62 per cent) were eight percentage points above the international mean, and only four percentage points lower than the mean percentage score achieved by students in the highest-scoring country.

Figure 2.2.2 shows the overall results for students in Year 9 (international eighth grade) in England on the six content areas within the written mathematics test.

Figure 2.2.2: Mean percentage scores on written mathematics tests



Source: Beaton *et al.*, 1996b

Overall, the performance of students in England was better in the Performance Assessment than in the written tests in mathematics when compared with the international means. It is likely that the National Curriculum emphasis on practical and investigative mathematics accounts for at least some of the apparent difference in achievement.

Students' performance on the two tasks mentioned above (*Calculator* and *Plasticine*) will be considered in more detail so as to illustrate more clearly their strengths and weaknesses that were evident with regard to mathematics tasks.

2.2.1 Calculator

This task required students to explore patterns in large numbers, to make predictions about numbers that would continue the pattern (without using a calculator) and to explore possible factors for a given three-digit number.

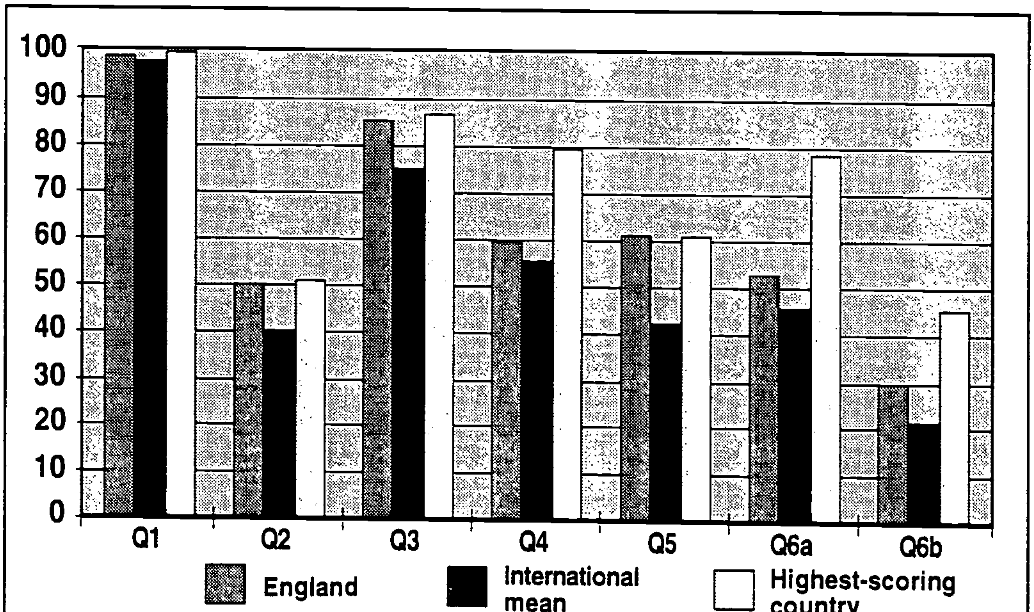
Figure 2.2.1.1 shows the results for students in England on each of the items within the task, together with international data for comparative purposes. Students in all participating countries achieved high scores on Q1, which simply asked students to use a calculator to find the answer to several multiplications. However, on Q2 and Q3, which required students to:

- identify a pattern in the answers given in Q1
- predict the answer to a further multiplication in the same pattern *without* using a calculator,

the results for students in England were only one percentage point lower than the highest-scoring countries in each case.

Figure 2.2.1.2 shows one student's (fully correct) responses to each of the questions in this task.

Figure 2.2.1.1: Performance on *Calculator* task



Source: Table 1.17 (Harmon *et al.*, 1997)

Figure 2.2.1.2: Performance on *Calculator* task

ITEMS 1 and 2

CALCULATOR

At this station you should have:

A calculator

Your task:
Use a calculator to help you explore a number pattern, and to find missing numbers.

Before answering the questions read these notes:

When you use the calculator:

- Make sure that you press the correct keys.
- Make sure that you read the display carefully.

1. Use the calculator to find the answers to these multiplications.

34 x 34 = 1156

334 x 334 = 111556

3334 x 3334 = 11115556

2. What do you notice about the muliplications and the pattern of answers?

The number of 1's in the answer is one more than the number of 3's in one of the numbers multiplied

eg. 34 x 34 no. of 3's = 1 no. of 1's = 2

334 x 334 no. of 3's = 2 no. of 1's = 3

The number of 5's in the answer is the same as the number of 3's in one of the numbers multiplied

eg. 334 x 334 no. of 3's = 2 no. of 5's = 2

3334 x 3334 no. of 3's = 3 no. of 5's = 3

ITEMS 3 to 6

3. Now use the pattern to write down what you think the answer will be to the multiplication below WITHOUT using the calculator.

(4 x 3's) (5 x 1's, 4 x 5's)

33334 x 33334 = 1111155556

4. Now write down what you think the answer will be to the multiplication below WITHOUT using the calculator.

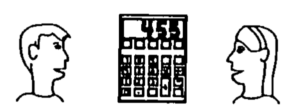
(7 x 1's, 6 x 5's)

3333334 x 3333334 = 11111115555556

(6 x 3's)

5. How did you find the answer to questions 3 and 4?

By counting the number of 3's in the number being multiplied and applying the rule I discovered previously, i.e. add 1 to the no. of 3's to get the no. of 1's; have the same no. of 5's as no. of 3's.



6. Rachel tells Ahmed that she multiplied two whole numbers together using a calculator and the answer was 455, but she's forgotten the numbers. She can remember two things about them:

- both numbers had 2 digits
- both numbers were less than 50

Please turn the page

ITEM 6 (contd.)

Ahmed tries several numbers. He began by putting 7 x 64 into the calculator. But Rachel said, "I can give you at least three reasons why those numbers can't be the ones I used. "What were Rachel's reasons?

a. Both numbers had 2 digits, and 7 only has one digit.

b. Both numbers were less than 50, and 64 is greater than 50.

c. The answer was 455, so both numbers must be odd, and 64 is even.

After thinking a bit about the problem, Ahmed made some more tries and found the two numbers.

- Now you try to find the numbers Ahmed found.

You may use any method you like. Write down each of your tries here.

21 x 21 = 441

21 x 23 = 483

19 x 23 = 437

19 x 25 = 475

17 x 25 = 425

17 x 27 = 459

15 x 31 = 465

13 x 35 = 455

The mean percentage score of students in England for Q5, in which they were asked to explain how they worked out their prediction for another long multiplication (without using a calculator) was higher than that of students in any of the other countries that participated in the Performance Assessment, and 19 percentage points above the international mean. In this context, it is worth noting that responses to questionnaires administered in the main survey found that calculators were used more frequently by both 13- and nine-year-olds in England than in any of the other countries that took part in TIMSS (Keys *et al.*, 1997a; 1997b). It is therefore possible that previous work using calculators to explore number patterns meant that students in England were more confident in answering this item than their counterparts in other countries.

Given these results, it is perhaps surprising that although a substantial proportion of students in England could identify and describe the pattern, they failed to apply it correctly when answering Q4. It is likely that some of the students who gave incorrect responses for Q4, but were able to answer Q5 correctly either assumed that Q4 would have one more number three in the question than Q3, or incorrectly counted the number of threes.

2.2.2 Plasticine

This task involved students in making four specified masses of plasticine: 20g; 10g; 15g; and 35g. The only equipment available to them was a simple balance, 50g and 20g masses and a supply of plasticine. Figure 2.2.2.1 shows one student's (fully correct) responses to each of the questions on this task.

The results for students in England on the *Plasticine* task were undoubtedly their worst on any of the Performance Assessment tasks. Figure 2.2.2.2 overleaf shows results for England together with international data for comparison.

Although their results were in line with the international means for Q1a and Q1b (in which students were asked firstly, to make a 20g mass of plasticine and secondly, to describe how they had done this) students in England performed poorly on all but one of the subsequent questions in this task. Not only were they less capable than their counterparts in other countries of producing a mass which was close to the target mass (for the 20g mass the permissible margin of error of ±2g; for the 15g and 35g masses the permissible margin was ±3g), but they were also less able to give a description of an appropriate strategy to achieve the correct mass. For the three questions which asked students to produce masses of 10g, 15g and 35g, their results were all below the international mean (by 4-19 percentage points), and were considerably lower than the results of students in the highest scoring countries (by 23-47 percentage points). However, surprisingly, performance on the final

Figure 2.2.2.1: Performance on *Plasticine* task

ITEM 1

PLASTICINE

At this station you should have:

- Some plasticine
- A balance
- Plastic bags
- A 20 g and a 50 g mass (weight)
- Coloured small circular sticky labels

Read ALL directions carefully.

Your task:
Use the balance to weigh different amounts of plasticine as carefully as you can. Then explain how you made them.

Before starting the task:

MAKE SURE THE PLANS ARE BALANCED WHEN EMPTY.

IF THEY ARE NOT, PUT YOUR HAND UP AND TELL THE TEACHER.

1a. Use the balance to make a lump of plasticine that weighs 20 g.

- When you have made the 20 g lump, write 20 g on a coloured label and stick it on the lump. Put the lump in a plastic bag.

1b. Write down how you made the 20 g lump.

I made the 20g by ~~be~~ putting a 20g balance in one of the pot on the scale and putting lumps of plastacine in the other till it balanced in the middle.

Check: 21g.

ITEMS 2 and 3

2a. Use the balance to make a lump of plasticine that weighs 10 g.

- When you have made the 10 g lump, write 10 g on a coloured label and stick it on the lump. Put the lump in the plastic bag with the 20 g lump.

2b. Write down how you made the 10 g lump.

I put ~~I~~ the 20g balance in one pot and made a plastacine ball 20g in the other the same way ~~re~~ by adding platacine then I took out the 20 g balance and cut the 20g plasticine ~~in half so it balance~~ in half put one on each end ~~of~~ of the scale till they balanced and used one as my 10g plastarine.

Check: 11g

3a. Use the balance to make a lump of plasticine that weighs 15 g.

- When you have made the 15 g lump, write 15 g on a coloured label and stick it on the lump. Place the 15 g lump in the plastic bag together with the other lumps.

3b. Write down how you made the 15 g lump.

I made a 20g lump like I had before then cut it and made a 10g lump using the scales. I put one 10g lump to one side then ~~m~~ cut the other ten and made a 5g lump by using the scales and making the scales even. I then put the 5g lump and stuck it to ~~to~~ the ten & I had put aside before from the twenty.

Check: 16g

ITEM 4

4a. Use the balance to make a lump of plasticine that weighs 35 g.

- When you have made the 35 g lump, write 35 g on a coloured label and stick it on the lump. Place the 35 g lump in the plastic bag with the other lumps.

4b. Write down how you made the 35 g lump.

I made the 35 by putting the 50 & 20g balace in one side of the scales and making a 70g plastacine lump by previous methods. I cut the ~~70g~~ 70g in half and balanced on scales I took one even half of 70g which is 35g.

Check: 36g

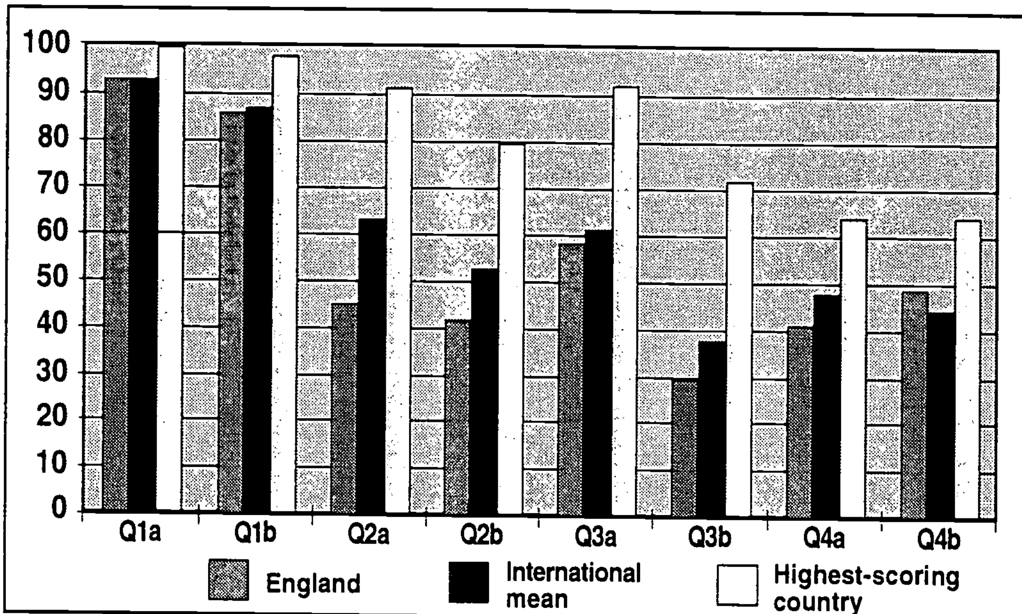
HAND IN THE BAG WITH THE LUMPS OF PLASTICINE YOU HAVE WEIGHED.
MAKE SURE YOUR NAME IS ON THE BAG

LEAVE EVERYTHING ELSE AS YOU FOUND IT.

BEST COPY AVAILABLE

question on this task (Q4b) was somewhat better, and at 48 per cent, was four percentage points above the international mean. An examination of students' responses, together with an appreciation of the equipment used in this task will suggest possible reasons for the poor results on some parts of this task as compared with the international means.

Figure 2.2.2.2: Performance on *Plasticine* task



Source: Table 1.17 (Harmon *et al.*, 1997)

Clearly, important factors determining the level of success on items in this task were:

a) development of an appropriate strategy to achieve the specified masses

b) ability to describe accurately the strategy used.

It is also evident that students who had an appropriate strategy would have scored marks for Q2a, Q3a and Q4a irrespective of their abilities to describe the strategy used. The data shown in figure 4, together with the illustrative examples of students' responses which follow, suggest that a considerable number of students in England were unable to develop an appropriate strategy, since the mean percentage correct was far lower for each part of the task after items Q1a and Q1b.

One major reason for relatively low results on Q2b and Q3b (explanations of the strategies used to produce the 10g and 15g masses) was students' lack of specificity in describing their approach, for example, making vague references to halving as shown in the example below.

Example 1

Q2b — *(Write down how you made the 10g lump.)*

I added and took away from a lump untill it was half of the 20g weight.

The coding criteria for students' responses were explicit and unambiguous in specifying acceptable responses: for a fully correct response, the method described had to be plausible AND the method had to refer to the use of the balance, as was done in these responses which showed two different approaches to the problem. The first example below is from a student who had used a halving strategy and the second, an additive strategy.

Example 2

Q2b — *(Write down how you made the 10g lump.)*

I found a 20g lump and split it in half and put halp n one bucket and half in the other until it weighed correctly.

Example 3

Q2b — *(Write down how you made the 10g lump.)*

To make the 10g lump I put the 50 g weight in the red bucket and the 20g weight in the yellow then I added the 20g lump of plasticine ~~to~~ the 20g weight. The I kept putting pieces of plastacine in the yellow bucket so each bucket would waght the same when it waighed the same I took all the plasticine ~~and which~~ (not including the 20glump) and took it out it shoud weigh 10g

Only 30 per cent of students in England offered answers such as those above. Twenty-four percent gave partially-correct responses. The majority of these (17 per cent) gave answers in which they described having used the 20g lump of plasticine made in the previous question (Q1a) and halved it, but failed to mention the use of the balance.

Example 4

Q2b — *(Write down how you made the 10g lump.)*

I made 10g lump of plasticine by making 20g and splitting it into two pieces.

However, in addition to responses such as those described above, some students' responses referred to a scale on the balance, and indicated that they had determined the 10g mass by allowing the pointer to move to half the distance it moved to when a 20g mass was placed in one pan. In reality, there was no such calibrated scale on the balance: the feature that students mistook for a calibrated scale was a simple guide to allow the user to level the balance pans before use - by adjusting the position of a load on the lever arm until the pointer rested on the zero on the 'scale'.

One response that illustrates this misconception is shown below.

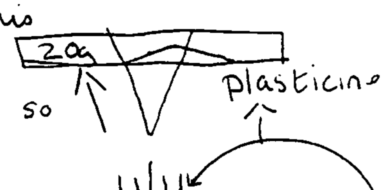
Example 5

Q2b — *(Write down how you made the 10g lump.)*

To know it the scales are balanced there a pointer and when its in the middle it is balanced

It looks like this

the pointer is in the middle so it is balanced



I made it so the pointer would point which is about half way.

Students who adopted this incorrect approach for Q2b often went on to use it in describing their strategy for making a 15g mass (Q3b), again assuming that the zeroing mechanism on the balance was an accurately calibrated scale.

Example 5 ***(continued)***

Q3b— *(Write down how you made the 15g lump.)*

I made the lump as Same as the 10g lump but instead of the pointer pointing to the end mark I made it point to the midelle mark.

At least one third of students gave incorrect responses for Q2b and Q3b, and of those who gave acceptable answers, a substantial proportion were only partially correct, indicating that they had failed to refer explicitly to the use of the balance. However, some students' responses were fully correct, being both plausible methods and mentioning the use of the balance, as in the example shown in Figure 2.2.2.1 shown earlier.

Interestingly, performance was better on Q4b, which asked students to describe their strategy for making a 35g lump of plasticine, than it had been on Q2b and Q3b (descriptions of strategies for making 10g and 15g lumps respectively). Not only was the mean percentage score for Q4b higher than those for Q2b and Q3b, it was also just above the international mean (by four percentage points). There were cases where students who had given incorrect responses to the two previous strategy questions (referring to the 'scale' markings on the balance) gave well-reasoned answers to Q4b, as in the example below.

Example 6

Q4b — *(Write down how you made the 35g lump.)*

I put the 20g weight & the lump of 15g that I made into 1 tray of the scales. (20 + 15 = 35.)
I put some plasticine into the other tray & ajusted it until it was equal weight to the other tray i.e. 35g

Other students offered alternative acceptable strategies, as for example shown in Figure 2.2.2.1 on page15 and the response shown below.

Example 7

Q4b — *(Write down how you made the 35g lump.)*

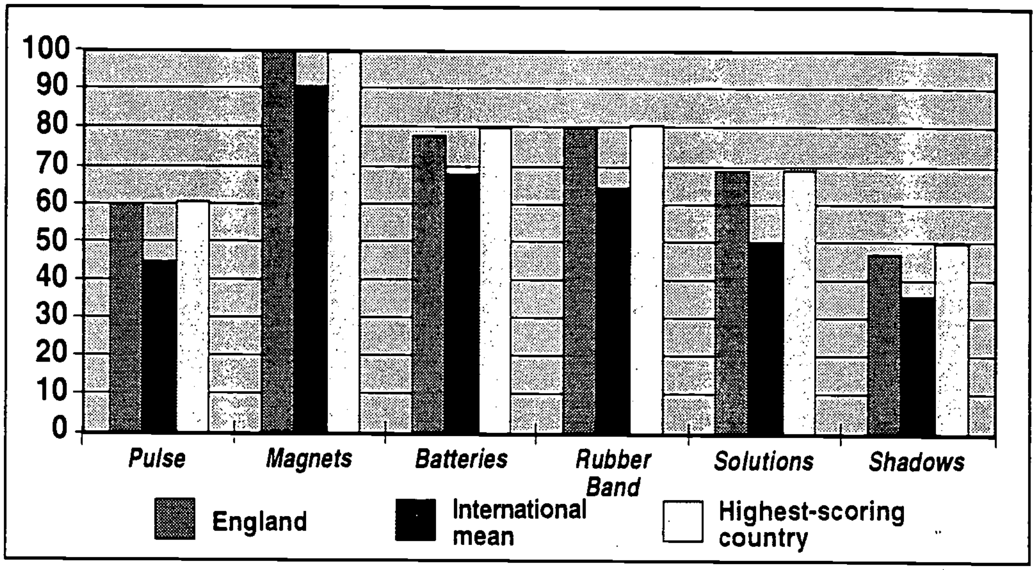
I got the 50g weight + made a 50g piece of plastine the I put that in 2 + made 25g. Then I got the 20g weight, I made a 20g of plasticine then put that in 2, + weighed them. to make 10g. thats how I got 35g.

It is likely that some of the students who were awarded marks for partially correct responses to Q2b (and, to a lesser extent, for Q3b) because they did not mention the use of the balance had in fact used it, and simply did not mention it because they focused on the main element (as they saw it) of halving a 20g mass, rather than on the use of equipment. On the other hand, it must be acknowledged that some students' descriptions of halving a 20g mass were succinct summaries of merely having halved a mass without necessarily having checked the resultant two masses on the balance to ensure they ended with two 10g lumps.

2.3 Results on science tasks

Figure 2.3.1 shows the overall performance of students in England on the six science tasks together with the international means and the results for these tasks from the highest-scoring countries[5] for comparative purposes.

Figure 2.3.1: Performance on the six science tasks

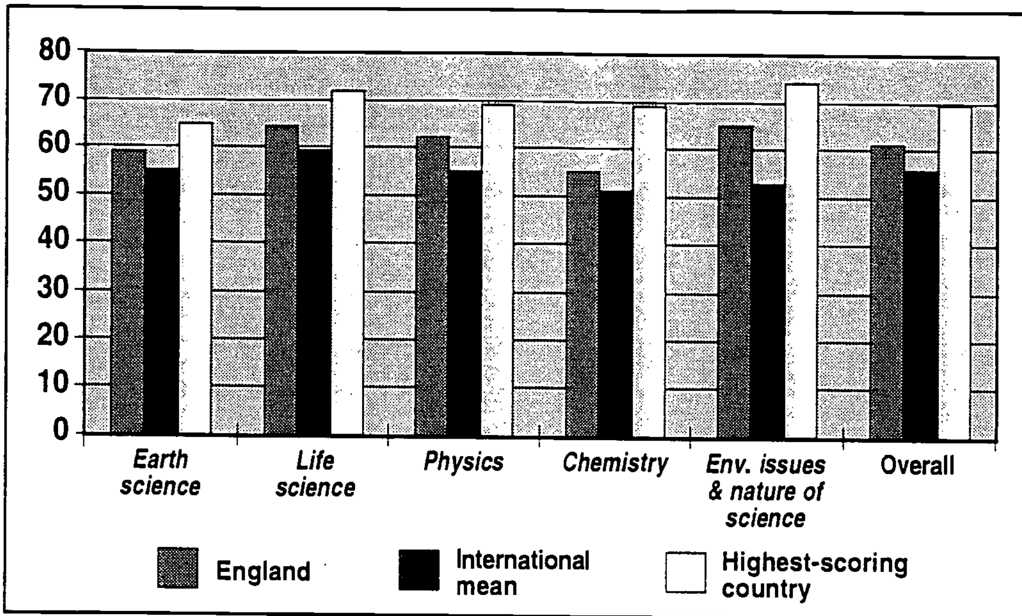


Source: Table 2.1 (Harmon *et al.*, 1997)

It is evident from Figure 2.3.1 that the performance of students in England was higher than the international mean for each one of the tasks: differences ranged from nine to 19 percentage points. For two of the tasks (*Magnets* and *Solutions*), no other country achieved higher mean percentage scores, and where students in other countries exceeded the results of students in England, the differences amounted to no more than four percentage points. This shows a high level of achievement across all the science tasks, and is consistent with the results for the written tests, in which the mean scores for students in England were above the international means in all of the five science content areas defined within the written achievement tests.

Figure 2.3.2 shows the overall results for students in Year 9 in England (international eighth grade) on the five content areas within the written science test, together with international data for comparison.

Figure 2.3.2: Mean percentage scores on written science tests



Source: Beaton *et al.*, 1996a

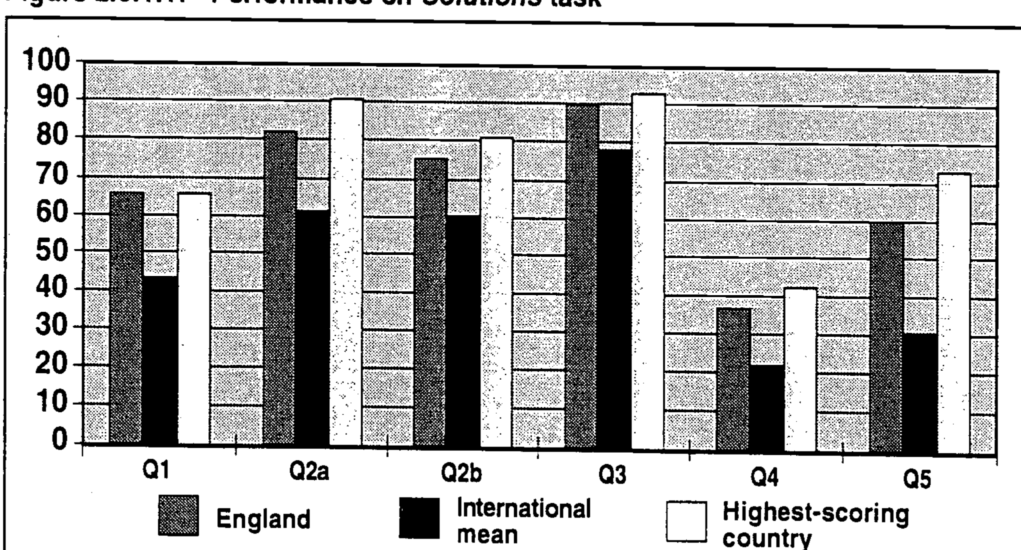
2.3.1 Solutions

As with the mathematics results, the mean percentage scores for each science task obscure the results on each of the items within the task. So as to demonstrate more clearly the strengths of students in particular areas, one of the science tasks (*Solutions*) will be examined in more detail.

Figure 2.3.1.1 shows the results for students in England on each of the items within the *Solutions* task. This task has strong links with the skills-related element of the National Curriculum for science, Sc1: Experimental and Investigative Science.

Figure 2.3.1.2 shows one student's (fully correct) responses to each of the questions in this task.

Figure 2.3.1.1: Performance on *Solutions* task



Source: Table 1.9 (Harmon *et al.*, 1997)

Figure 2.3.1.2: Performance on *Solutions* task

ITEM 1

SOLUTIONS

At this station you should have:

- Hot and cold water
- Several beakers
- Some tablets
- A stirrer
- A clock or watch with a second hand
- A thermometer
- A 30 cm ruler

Read ALL directions carefully.

> **Your task:**
> Investigate what effect different temperatures have on how long it takes a tablet to dissolve.

This is what you should do:

- Plan an experiment to find out what effect different temperatures have on how long it takes a tablet to dissolve.

1. Write your plan here. Your plan should include
   - what you will measure
   - how many measurements you will make
   - how you will present your measurements in a table.

I will measure how long it takes for a tablet to dissolve in a certain temperature.
I will make 4 measurements, 1 at 60 2 at 40 3 at 20 4 at 10 in °C
The water will be 200 ml deep.
I will stir very slowly, in order to keep the same speed
I know when the tablet has fully dissolved, when there is no more tiny particles on the surface.

ITEMS 2 and 3

2. Carry out your tests on the tablets. Make a table and record all your measurements.

1	2	3	4
18 Seconds 73 hundreds of a second At 60°C	36 Seconds 77 hundreds of a second At 40°C	45 Seconds 34 hundreds of a second At 20°C	57 Seconds 48 hundreds of a second At 10°C

3. According to your investigation, what effect do different temperatures have on how long it takes a tablet to dissolve.

If the temperature is higher, the tablet will dissolve more quickly. Between 60°C and 40°C there is a very big difference. So, If you wanted to dissolve these tablets quickly, 60°C is a good operating temperature.
As the temperature gets lower, there are not very big gaps between the times.

ITEM 4

4. Explain why you think different temperatures have this effect.

I think that the hotter the temperature, the more the molecules are excited, they are probably moving faster when they are hotter. So these excited molecules, try to break up the solid, and try and weave their way in to the gaps in the molecules

5. If you changed your plan while you were working, describe the changes you made and why you made them. If you did not change your plan, write "No change".

No change

EMPTY YOUR BEAKERS INTO THE WASTE CONTAINER, DRY THEM, AND LEAVE EVERYTHING THE WAY YOU FOUND IT.

29 BEST COPY AVAILABLE 30

The performance of students in England exceeded the international means for individual parts of the *Solutions* task by 12-29 percentage points. The overall mean percentage score for the task was 68 per cent, which, together with Singapore, was the highest score achieved by any country on this task.

Although performance on this task was consistently higher than the international mean, two particular items within the task are particularly noteworthy as they have strong links with the emphasis placed in the National Curriculum for science on the design and execution of fair tests: Q1 which asked students to plan an investigation, and Q5, which asked students to evaluate the design of their investigation by indicating where, if at all, during the course of the investigation, they had amended their original plan, and the reasons for the amendments. These questions are strongly related to that part of the National Curriculum for science which is concerned with planning experimental work (Sc1: Experimental and Investigative Science).

During the course of ongoing science work under the National Curriculum students in England will have had opportunities to suggest investigations, plan how to conduct them, carry out the investigations and analyse the results. The investigations will have provided opportunities for students to apply skills in collecting, recording and interpreting data. A final stage in this type of work would typically involve reflecting on the design of the investigation, determining, for example:

- was the design and execution of the investigation 'fair', or were there variables that had not been controlled which therefore made the results invalid?
- had the data collected enabled the student to draw a conclusion?
- were there any ways in which the conduct of the investigation could have been improved?

It is likely that students' experiences in the design and conduct of science investigations as part of their National Curriculum work in science gave them useful prior experience to draw upon when answering the questions on the *Solutions* task.

The mean percentage score for students in England on Q1 (in which they were asked to outline their plan for the investigation) was 66 per cent, the highest of any of the participating countries, and 22 percentage points above the international mean for this question. There were, however, interesting variations in students' responses to Q1. At the workstation, students were provided with a quantity of hot water (approximately 60(-65(C) in a Thermos flask, and there was a supply of cold water available within the laboratory. Some students chose to use only the hot and cold water provided, whereas others (as shown in Figure 2.3.1.2 above) also mixed the two to obtain samples of water at a range of different temperatures.

Some students demonstrated that they were aware of the importance of repeating the test to check their results, as in the following example.

Example 8

Q1 — *(Write your plan including measurements and how you will present them in the table.)*

I will measure the amount of time it will take for the tablet to completly dissolve. I will just take the on measurement when it has dissolved. I will use 100ml of the hot / cold water and stir the tablets all of the time untill they have dissolved. I will do each experiment 3 times

Q2— *(Carry out your tests on the tablets. Make a table and record all your measurements)*

Try	water temp °c	time to dissolve
1	19 °c	54 seconds
2	19 °c	51 seconds
3.	19 °c	54 seconds
1.	47 °c	38 seconds
2.	47 °c	37 seconds
3	47 °c	34 seconds

Some students designed and carried out tests in which they investigated the effects of not stirring/stirring the mixture.

Example 9

Q1 — *(Write your plan including measurements and how you will present them in the table.)*

1) fill one beaker with cold water and one beaker with hot water.
2) measure the temperater of the water
3) Put one tablet in each beaker.
4) time the lenghth of time taken for the tablet to dissolve
5) record results
6) repeat experiment but this time stir for 30 seconds.

NOTE: 200ml in each beaker.

Example 9 ***(continued)***

Q2— *(Carry out your tests on the tablets. Make a table and record all your measurements)*

Results table.

experiment 1

Temp °C of water	Time (s)
18 °C	52(s)
53 °C	34(s)

experiment two

Temp °C water	Time(s)
18 °C	47
53 °C	29

Q3— *(What effect do different temperatures have on how long it takes the tablet to dissolve?)*

experiment 1

According to my results if the temperature is higher then it takes less time for the tablet to dissolve.

experiment 2

According to my results if you stirr the mixture then it takes even less time to dissolve but the hotter water dissolves first.

Some students identified other areas of interest which they included in their investigation, which might not have been anticipated: the first of the following examples shows a student who wanted to determine the water temperature *after* the tablet had dissolved, and the second example shows the work of a student who wanted to find out if the quantity of hot or cold water respectively affected the rate at which the tablet dissolved.

Example 10

Q1 — *(Write your plan including measurements and how you will present them in the table.)*

Get above equipment. Then pour out the hot and cold water into 2 beakers. keeping a constant recording of the temp. of the hot water. Then put a tablet into the hot water. Time how long it takes to dissolve it. Record this. Then do the same for the cold water. Again record this.

NB/ Before this, record how much water is in the beakers - should be equal.

Example 10 ***(continued)***

Q2— *(Carry out your tests on the tablets. Make a table and record all your measurements)*

	temp. at start	temp. at end	time taken to dissolve tablet
Hot water	50°c	49°c	37sec.
Cold water	20°c	18°C	63 sec

(amount of water in beaker - 200mL)

Example 11

Q2— *(Carry out your tests on the tablets. Make a table and record all your measurements)*

Table			
Test	temp	(Secs) dissolve	How much water.
1. Cold	20°C.	43.21.	150ml.
2. cold	20°C	41·12	100ml.
1. Hot	56°C	17·37.	150ml
2. Hot	55°C	24.06	100ml.

The mean percentage score for students in England on Q5 was 59 per cent, 29 percentage points above the international mean, and exceeded only by students in Romania (with a mean percentage score of 73 per cent).

An interesting feature of the marking criteria for Q5 was that students were given full marks for indicating that they had made 'No change' to the plan they had drawn up for the investigation during the course of the activity, but ONLY if their plan provided in Q1 fulfilled the criteria for an acceptable investigation (see Figures 2.3.1.3 below and 2.3.1.2 above).

Figure 2.3.1.3: Criteria for a fully correct response for Q1

i. Describes how the investigation will be conducted.

ii. States what variables will be measured or observed; includes both solution time and temperature.

iii. Provides control for other variables, or renders other variables irrelevant by design.

Total possible marks: 2

Source: Figure 1.8 (Harmon *et al.*, 1997)

2.4 Correlations between students' performance on the written tests and the performance assessment tasks

The preceding sections have shown how the two student achievement components of TIMSS (the written tests and the practical tasks) relate to the National Curriculum Orders for mathematics and science in England, compared students' results with international data and identified strengths and weaknesses in students' results on some of the Performance Assessment tasks. Since the written tests are more closely related to knowledge and understanding, and the practical tasks to process skills, it is of interest to determine the extent to which students' results on the practical tasks are correlated with their results on the written tests. Correlation coefficients (Pearson) have been calculated between students' raw scores on each of the 12 tasks and the mathematics and science scores achieved by the students that attempted each of those tasks: these are shown in Table 2.4. The correlations between students' scores on the practical and the written components are all highly significant ($P<0.001$ i.e. the probability of these correlations occurring by chance is fewer than one in a thousand).

Table 2.4: Correlation coefficients between each of the 12 tasks and mean mathematics and science scores on written tests

Task	Correlation coefficients	
	Mathematics	Science
Dice	0.54	0.36
Calculator	0.55	0.40
Folding and Cutting	0.48	0.51
Around the Bend	0.53	0.51
Packaging	0.41	0.43
Plasticine	0.51	0.33
Pulse	0.45	0.47
Magnets	0.22	0.22
Batteries	0.52	0.42
Rubber Band	0.57	0.43
Solutions	0.47	0.48
Shadows	0.53	0.46

The correlation coefficients vary between tasks and also in the correlations between particular tasks and the mathematics and science scores on the written tests. Four of the mathematics tasks (*Dice*, *Calculator*, *Around the Bend* and *Plasticine*) showed strong correlations (greater than 0.5) with students' scores on the written mathematics tests; this is not surprising, since one would expect students who do well on written tests also to do well in practical mathematics tasks. However, there were also strong correlations between three of the science tasks and students' scores on the written mathematics tests (*Batteries*, *Rubber Band* and *Shadows*). This is most probably due to the tasks' including items which involved the application of mathematical skills, such as determining mathematical relationships in the investigative data.

Most of the correlations between the students' results on the Performance Assessment tasks and on the written tests in mathematics and science were between 0.4 and 0.55, which suggests that although there was some overlap of skills tested, these two aspects of TIMSS also each tested additional skills and/or knowledge which the other component did not.

These correlations should be set against the context of the correlation of 0.73 between the scores on the written mathematics and science tests achieved by all Year 9 students in England. In essence, this means that there is a stronger correlation between students' results on the written tests in both subjects than between their results on the Performance Assessment tasks and the written tests.

The results of this analysis are consistent with what one would expect, taking into account the relationship that each component has to the National Curriculum Orders in place in England. The written tests in mathematics and science share similarities with those parts of the Orders which are related to knowledge and understanding in mathematics and science; students' results on both subjects were highly correlated. The practical tasks had a similar emphasis to the part of the National Curriculum Orders relating to applying mathematical and scientific skills and conducting investigations; students' results on these tasks were less strongly correlated with their results on the written tests.

3. CONCLUDING REMARKS

The 12 tasks that comprised the Performance Assessment for 13-year-olds gave students opportunities to demonstrate their skills in carrying out routine activities such as taking measurements, recording results and summarising observations together with investigative and analytical activities such as planning, carrying out and reflecting on the design of an investigation, drawing conclusions and making predictions based on experimental data.

The tasks required students to record results, often in the form of a table. Some required additional work related to these results, such as the construction of a graph or making predictions based on information available. These aspects of carrying out practical work are closely linked with the one content area in the TIMSS written mathematics test in which the results for students in England were above the international mean: *Data representation, analysis and probability*. It is possible that students did well in data representation items in the written tests because they had had extensive experience of this type of work during the course of practical activities in mathematics and science.

With more countries placing increasing emphasis on developing students' problem-solving and investigative skills, it seems appropriate to conclude that the results on these two components of TIMSS have given students in 21 countries an opportunity to demonstrate both their knowledge and understanding of concepts in mathematics and science, and their practical and investigative skills in these subjects. At a national level, this information supplements that collected by means of National Curriculum assessment for students in Year 9, but, importantly, enables comparisons to be drawn between the performance of students in England and in other countries. Those who were concerned by the relatively poor performance of students in England on the written mathematics tests will no doubt take some comfort from the results on the TIMSS Performance Assessment, which showed that in addition to maintaining consistently high levels of achievement in all aspects of science, there are also aspects of mathematics in which students in England are doing relatively well.

It is evident that countries that administered the practical tasks as well as the written tests in mathematics and science have been rewarded with valuable national data as well as the opportunity to draw international comparisons in both aspects. Looking to the future, it is clear that future international studies in mathematics and science should seriously consider the benefits to be gained by including a practical component in the data collection effort, so that the full range of student activity, relating to both knowledge and understanding *and* process skills, can be assessed.

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