The Irish Journal of Education, 2002, *xxxiii,* pp. 53-70.

THE PERFORMANCE OF IRISH STUDENTS IN SCIENTIFIC LITERACY IN THE PROGRAMME FOR INTERNATIONAL STUDENT ASSESSMENT (PISA)

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The OECD Programme for International Student Assessment in 2000, which was administered to representative national samples of 15-year olds in Ireland and in 27 other OECD countries, included an assessment of scientific literacy. The assessment covered both knowledge of scientific concepts and ability to engage in scientific thinking in a range of 'real life' contexts. Irish students achieved a mean score that was higher than the OECD country average but lower than the mean scores of students in six countries including the United Kingdom, Canada, and New Zealand. In Ireland, as in most OECD countries, the performance of male and female students did not differ significantly. Student-level variables associated with performance included socioeconomic status and having studied science at junior-cycle level. School-level variables associated with performance included school type (secondary, community-comprehensive, or vocational) and school designated disadvantaged status. Variation between schools in Ireland was smaller than in most OECD countries.

In previous international studies of science achievement, the performance of students in Ireland has been rather poor relative to that of students in other participating countries. In the second International Assessment of Educational Progress (IAEP II), conducted in 1991 with samples of 9- and 13-year olds, Irish 9-year olds had the lowest mean score of the 10 participating countries, while 13-year olds ranked 14th out of 15 participating countries (Martin, Hickey, & Murchan, 1992), and 9th out of the 10 OECD countries that participated (OECD, 1993).

In the Third International Mathematics and Science Study (TIMSS), conducted in 1995, Irish 4th class (primary level) pupils ranked 10th of 17 OECD countries, achieving a mean score that was not significantly different from the OECD country average (OECD, 1997). Irish students in 2nd year (post-primary level) ranked 9th of 17 OECD countries, also achieving a mean score that was not significantly different from the OECD average. Irish students in 4th class performed better than on the test as a whole in one science content area (life science), at about the same level in another area (earth science), and less well in two areas (environmental issues and the nature of science; physical science) (Martin, Mullis, Beaton, Gonzalez, Smith, & Kelly, 1997). Irish students in 2nd year performed at about the same level as on the test as a whole in three content areas (earth science; life science; environmental issues and the nature of science), and significantly less well in two (physics; chemistry) (Beaton, Mullis, Martin, Gonzalez, Smith, & Kelly, 1996).

The OECD Programme for International Student Assessment (PISA) in 2000 provided the opportunity to again examine the achievements in science of Irish students (in this case of 15-year olds) in an international context. Reading literacy was the main domain assessed. However, scientific literacy and mathematics literacy were included as minor domains (to be assessed again in 2003 and 2006). Coverage of the scientific domain (with 35 items) was not as comprehensive as in reading literacy (141 items). Five-ninths of students in each participating country were asked to attempt scientific literacy items, while all were asked to attempt items in the reading literacy domain.

In this paper, following a definition of scientific literacy, the framework for the literacy assessment is presented. The performance of Irish students in the assessment is then described in the context of students in other OECD countries. Student and school variables that were found to be associated with the performance of Irish students are then identified. Finally, links between PISA scientific literacy and science in the Junior Certificate syllabus are described.

SCIENTIFIC LITERACY

The term 'scientific literacy' implies that both scientific knowledge (knowledge about science) and the application of scientific processes are important. In PISA 2000, scientific literacy was 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, 1999, p. 60)

The definition reflects a concern with the capacity of students to draw appropriate conclusions from information, to critically evaluate claims made by others on the basis of evidence, and to distinguish opinion from scientifically-based statements or conclusions. Scientific knowledge is viewed as consisting of definitions, names, and terms. It also includes an understanding of scientific concepts, the limitations of scientific knowledge, and science as a human activity.

THE PISA SCIENTIFIC LITERACY FRAMEWORK

The philosophy underlying PISA scientific literacy is rooted in STS (Science-Technology-Society) or 'context-based' approaches to science education, which have emerged over the past 25 years. Such approaches use contexts and applications as the starting point for developing understanding of scientific ideas. Solomon and Aikenhead (1994) identified several categories of STS approaches, all of which aim to promote scientific literacy through developing understanding of one or more of the following: what is meant by science and technology, and how they relate to each other; the ways in which science and technology affect society, including environmental, ethical, and economic/industrial dimensions; the way scientists work; and the nature of science.

A number of arguments have been put forward for the inclusion of STS approaches in science curricula and assessment frameworks. One such argument, which may be termed 'citizen science', holds that people need to know something about science to help them to think and act appropriately on scientific matters which may affect their own lives and the lives of other members of local, national, and global communities. Another, which may be termed 'relevant science', holds that science which emphasizes applications rather than abstractions is more likely to foster interest in students.

The STS movement developed through political impetus, with commentators in countries such as the USA arguing that if scientific and technical advances lagged behind, so would the economy and global competitiveness. It also developed through pedagogical and curricular concerns about science, relating to low uptake in the physical sciences and the appropriateness of existing science courses for non-science specialists (Solomon & Aikenhead, 1994). Because PISA takes a human capital approach, emphasizing the value of lifelong learning and the preparation of students for future participation in adult society, it is not surprising that the STS approach, justified on the basis of 'citizen science', is apparent in the PISA assessment framework.

Five *scientific processes* are distinguished in the assessment (see Shiel, Cosgrove, Sofroniou, & Kelly, 2001). These are: recognizing scientifically investigable questions; identifying evidence needed to draw a scientific conclusion; drawing or evaluating conclusions; communicating valid conclusions; and demonstrating understanding of scientific concepts. The last process, tapped in 43% of items, receives the most emphasis. Three broad *science areas* are also identified: science in earth and the environment; science in life and health; and science in technology. The three areas receive about equal emphasis. The distribution of test items by *science theme* shows that the physical sciences (i.e., physics and chemistry) are not as strongly emphasized as other aspects of science. The *scientific contexts* in which the questions are embedded cover four broad areas: global (e.g., the greenhouse effect), historical (e.g., scientific discoveries), personal (e.g., food intake and energy use), and public (e.g., water treatments in a local community). The questions are most commonly embedded in global contexts (46% of items) (Table 1).

Table 1
Distribution of Scientific Literacy Items by Dimensions of the Scientific Literacy Framework

Dimension	Number of Items	Percent of Items	Dimension	Number of Items	Percent of Items
Science Processes			*Science Themes*		
Communicating conclusions	3	8.6	Atmospheric change	5	14.3
Demonstrating understanding	15	42.9	Biodiversity	1	2.9
Drawing/evaluating conclusions	7	20.0	Chem/Phys change	1	2.9
Identifying evidence/data	5	14.3	Earth and universe	5	14.3
Recognizing questions	5	14.3	Ecosystems	3	8.6
			Energy transfer	4	11.4
Science Areas			Form and function	3	8.6
Earth/environment	13	37.1	Genetic control	2	5.7
Life and health	13	37.1	Geological change	1	2.9
Technology	9	25.7	Human biology	3	8.6
			Physiological change	1	2.9
Science Contexts	16	45.7	Structure of matter	6	17.1
Global					
Historical	4	11.4			
Personal	8	22.9	Total	35	100.0
Public	7	20.0			

Source: Shiel et al. (2001), p. 12

In the assessment, students were presented with stimulus texts and accompanying questions. A stimulus text may be divided into several parts, each followed by one or more questions. The questions take the form of either multiple-choice items in which students choose one of a set of possible responses or constructed response items in which students are asked to write their own answers. Some constructed response questions are short, requiring only a word or short phrase, while others are longer, requiring one or more sentences. The 35 science questions (and associated texts) are distributed across test booklets, and individual students attempted a subset of these items.

Sample Tasks

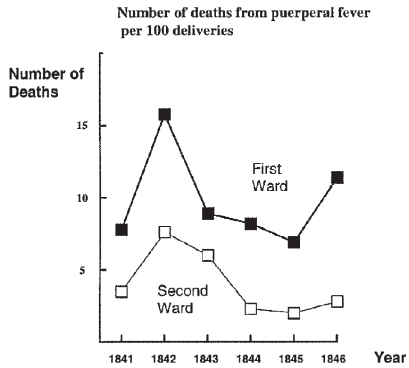
The PISA assessment framework for scientific literacy may be illustrated by a number of items released after the 2000 assessment[1]. The first stimulus passage and question discussed here (see Figure 1) are taken from the unit entitled Semmelweis. The unit concerns the scientist Ignaz Semmelweis, who discovered in the 1840s that puerperal fever was caused by bacterial infection. The passage, which is quite long and dense in content and historical in context, covers the area of life and health. The question asks students to adopt the point of view of Semmelweis, to evaluate the scientific evidence gathered, and to explain why a hypothesized cause of puerperal fever (earthquakes) is unlikely to be true. The question uses the constructed response format, and credit is given for both partially correct and more sophisticated, fully correct responses. The question is quite difficult. The scaled item difficulties (which are on the same scale as the student performance) are 679 points for a fully correct answer, and 651 for a partially correct answer. For full credit, students must identify and correctly communicate that the rate of deaths in two adjacent wards differ. Just 21.3% of students across OECD countries, and 21.6% of Irish students, obtained full credit. For partial credit, students must give another plausible reason, but one which fails to take into account the adjacency of the two wards and the differential death rate. Just 9.9% of students across OECD countries and 7.3% of Irish students obtained partial credit. The high rate of missing responses – almost 28% in OECD countries and close to 18% in Ireland – suggests that the relatively high level of complexity and reading load in the stimulus may have discouraged some students from attempting the question.

1 The PISA assessment framework (OECD, 1999) provides a more detailed description of the components of the assessment. Additional examples of items may be found in OECD (2002).

Figure 1
First Sample Passage and Question from the PISA 2000 Assessment of Scientific Literacy

"July 1846. Next week I will take up a position as 'Herr Doktor' at the First Ward of the maternity clinic of the Vienna General Hospital. I was frightened when I heard about the percentage of patients who die in this clinic. This month not less than 36 of the 208 mothers died there, all from puerperal fever. Giving birth to a child is as dangerous as first-degree pneumonia."

These lines from the diary of Ignaz Semmelweis (1818-1865) illustrate the devastating effects of puerperal fever, a contagious disease that killed many women after childbirth. Semmelweis collected data about the number of deaths from puerperal fever in both the First and the Second Wards (see graph).



Physicians, among them Semmelweis, were completely in the dark about the cause of puerperal fever. Semmelweis continues:

"December 1846. Why do so many women die from this fever after giving birth without any problems? For centuries science has told us that it is an invisible epidemic that kills mothers. Causes may be changes in the air or some extraterrestrial influence or a movement of the earth itself, an earthquake."

Nowadays not many people would consider extraterrestrial influence or an earthquake as possible causes of fever. But in the time Semmelweis lived, many people, even scientists, did! We now know it has to do with hygienic conditions. Semmelweis knew that it was unlikely that fever could be caused by extraterrestrial influence or an earthquake. He pointed at the data he collected (see graph) and used these to try to persuade his colleagues.

Question
Suppose you were Semmelweis.
Give a reason (based on the data Semmelweis collected) why puerperal fever is unlikely to be caused by earthquakes.

Percent Choosing Each Response

	Ireland	*OECD*	*Key*
Incorrect	51.0	43.5	Earthquakes do not cause fever; is another cause
Partially Correct	9.9	7.3	Earthquakes infrequent; effect people outside wards; not always associated with fever
Fully Correct	21.3	21.6	Refer to difference between number of deaths in the two wards
Correct	26.2	25.2	
Missing	17.8	27.7	

A second text segment and accompanying question, also taken from the *Semmelweis* unit, is shown in Figure 2. This question is multiple-choice in format, and much easier than the previous question, having an item difficulty of 506. The question requires students to recognize questions that can be answered by scientific investigation. Students have to make the link between the causes of death of two groups: women in a maternity ward and student doctors involved in dissection work. Across OECD countries, 63.8% of students selected the correct answer; in Ireland, 69.8% of students were correct.

Figure 2
Second Sample Passage and Question from the Pisa 200 Assessment of Scientific Literacy

Part of the research in the hospital was dissection. The body of a deceased person was cut open to find the cause of death. Semmelweis recorded that the students working on the First ward usually took part in dissections on women who died the previous day, before they examined women who had just given birth. They did not pay much attention to cleaning themselves after the dissections. Some were even proud of the fact that you could tell by their smell that they had been working in the mortuary, as this showed how industrious they were!

One of Semmelweis' friends died after having cut himself during such a dissection. Dissection of his body showed he had the same symptoms as mothers who died from puerperal fever. This gave Semmelweis a new idea.

Question
Semmelweis' new idea had to do with the high percentage of women dying in the maternity wards and the students' behaviour.
What was this idea?

A* Having students clean themselves after dissections should lead to a decrease in puerperal fever.
B Students should not take part in dissections because they may cut themselves.
C Students smell because they do not clean themselves after a dissection.
D Students want to show that they are industrious, which makes them careless when they examine the women.

Percent Choosing Each Response		
	Ireland	*OECD*
A*	69.8	63.8
B	6.1	7.5
C	6.6	6.0
D	12.7	14.5
Missing	4.9	8.2

PERFORMANCE ON THE PISA 2000 ASSESSMENT OF SCIENTIFIC LITERACY

Performance on the PISA 2000 assessment of scientific literacy is reported here in terms of country mean scores and the average scores of students who scored at key benchmarks (the 10th and 90th percentiles). Qualitative descriptions corresponding to key points on the OECD-wide scientific literacy scale are given to provide insights into the meanings of scores at different points on the scale.

Overall Performance

Using Item Response Theory methodology, which places item difficulties and student abilities on the same scale, the OECD mean was set at 500 and the standard deviation at 100. Ireland's mean score of 513.4 gave it a rank of 9th of 27 OECD countries (Table 2). Six countries had mean scores that were significantly higher (Korea, Japan, Finland, the UK, Canada, New Zealand). The gap between Korea (the highest scoring country) and Ireland is almost two-fifths of a standard deviation (38.7 points) on the international scale. Irish students achieved a mean score that is not significantly different from the mean score of students in seven countries, including Australia, Sweden, and France. Irish students outperformed students in 13 countries including Hungary, Switzerland, and Germany.

All six countries with significantly higher mean scores than Ireland on scientific literacy also have significantly higher mean scores on mathematical literacy, while just one (Finland) has a significantly higher mean score on reading literacy (OECD, 2001). Although it would seem that strong performance on mathematical literacy (at the country level) may be linked to strong performance on scientific literacy, it is also the case that four countries with mean scores on mathematical literacy that are significantly higher than Ireland's (Australia, Sweden, France, Austria) have mean scores on scientific literacy that are not significantly different.

The standard deviation associated with the mean scientific literacy score for Irish students (91.7 points) is lower than the OECD average standard deviation, and than the standard deviations for the UK (98.2), the USA (101.1), and France (102.4). On the other hand, Ireland's standard deviation is smaller than that of Korea (80.7). These findings indicate that the spread of achievement is narrower among students in Korea than in Ireland, while the spread in Ireland is narrower than in the UK and the USA.

Table 2
Mean Achievement Scores and Standard Deviations, and Scores at the 10th and 90th Percentiles, of Students in OECD Countries on PISA Scientific Literacy

Country	Mean (SE)	SD (SE)	Mean Score at 10th Percentile	Mean Score at 90th Percentile
Korea, Republic of	552.1 (2.69)	80.67 (1.81)	442.5 (5.27)	651.7 (3.86)
Japan	550.4 (5.48)	90.47 (3.00)	430.0 (9.87)	659.3 (4.70)
Finland	537.7 (2.48)	86.29 (1.21)	424.8 (4.17)	645.5 (4.25)
UK	532.0 (2.69)	98.18 (2.02)	401.5 (5.97)	656.1 (4.73)
Canada	529.4 (1.57)	88.84 (1.05)	402.4 (4.73)	640.9 (2.19)
New Zealand	527.7 (2.40)	100.74 (2.25)	392.5 (5.16)	653.0 (4.96)
Australia	527.5 (3.47)	94.23 (1.56)	402.4 (4.73)	646.4 (5.08)
Austria	518.6 (2.55)	91.25 (1.74)	397.7 (3.95)	633.2 (4.12)
Ireland	513.4 (3.18)	91.74 (1.71)	394.4 (5.73)	630.2 (4.64)
Sweden	512.1 (2.51)	93.21 (1.42)	389.8 (4.60)	629.7 (3.41)
Czech Republic	511.4 (2.43)	93.92 (1.42)	389.4 (4.00)	632.0 (4.13)
France	500.5 (3.18)	102.36 (1.98)	363.5 (5.38)	630.6 (4.21)
Norway	500.3 (2.75)	95.54 (2.04)	377.4 (6.63)	619.5 (3.93)
USA	499.5 (7.31)	101.08 (2.92)	367.6 (10.00)	628.0 (6.98)
Hungary	496.1 (4.17)	102.52 (2.31)	360.8 (4.92)	629.2 (5.05)
Iceland	495.9 (2.17)	87.78 (1.60)	380.7 (4.30)	606.7 (4.07)
Belgium	495.7 (4.29)	110.97 (3.81)	346.3 (10.2)	629.7 (2.57)
Switzerland	495.7 (4.44)	100.06 (2.43)	365.5 (5.42)	625.5 (6.43)
Spain	490.9 (2.95)	95.38 (1.76)	366.9 (4.31)	612.6 (3.92)
Germany	487.1 (2.43)	101.95 (1.96)	350.2 (6.03)	618.1 (3.51)
Poland	483.1 (5.12)	96.84 (2.70)	359.1 (5.76)	610.1 (7.56)
Denmark	481.0 (2.81)	103.21 (1.99)	346.6 (5.32)	612.5 (4.36)
Italy	477.6 (3.05)	98.04 (2.59)	348.8 (6.16)	602.1 (4.02)
Greece	460.6 (4.89)	96.90 (2.57)	334.1 (8.34)	585.2 (5.34)
Portugal	459.0 (4.00)	89.01 (1.61)	343.0 (5.13)	575.2 (5.00)
Luxembourg	443.1 (2.32)	96.34 (1.95)	319.7 (6.79)	563.2 (4.44)
Mexico	421.5 (3.18)	77.07 (2.09)	325.5 (4.60)	524.8 (5.50)
OECD Country Average	500.0 (0.65)	100.0 (0.46)	365.5 (1.03)	626.9 (0.80)

Mean achievement significantly higher than Ireland
Mean achievement not significantly different from Ireland
Mean achievement significantly lower than Ireland

Source: OECD (2001), Table 3.3

Performance at Key Benchmarks

In addition to providing information about the overall performance of students, PISA provides information on performance at key benchmarks within and across countries. The mean scores of students at the 10th and 90th percentiles are taken as indicators of the performance of low- and high-scoring students respectively.

The mean score of Irish students at the 10th percentile (394.4 points) ranks their performance as 7th among OECD countries at this marker (Table 1). The mean scores of students at this marker in Korea (442.5), Japan (430.0), and Finland (424.8) are significantly higher than the Irish mean, indicating comparatively better performance among low achievers in those countries. Countries with very low scores at the 10th percentile include Greece (334.1), Mexico (325.5), and Luxembourg (319.7).

The mean score of Irish students at the 90th percentile (630.2) ranks Ireland 10th among OECD countries. All countries with overall mean scores that are significantly higher than Ireland's scored significantly higher at the 10th percentile. The countries with the highest mean scores at the 90th percentile are Japan (659.3) and the U.K. (656.1). The mean score of students at the 90th percentile in the UK is 25.9 points (one quarter of a standard deviation) higher than the mean score of Irish students at that marker.

Variation in Achievement Between Schools

In Ireland, the variation in scientific literacy achievement that can be attributed to differences between schools is 14.1 percent. This is lower than the corresponding OECD country average of 30.6%, suggesting that, relative to the situation in other countries, Irish schools do not differ greatly from one another in scientific literacy. Countries with lower between-school variation in achievement include Finland (6.6%), Iceland (7.6%), and Sweden (8.2%). Countries with high between-school variance include Poland (51.4%), Hungary (52.8%), Belgium (55.4%), and Austria (55.8%). It was not possible to separate the between-class and between-student components of within-school variance, as PISA 2000 did not provide information on the classes which students attended.

An Interpretation of Scores on the Scientific Literacy Scale

Since the scientific literacy assessment comprised only 35 test items, it was not possible to generate overall proficiency scales, or to scale for particular aspects of scientific literacy. However, descriptions of the skills associated with different points on the scientific literacy scale were provided. These are based on the response patterns of students across OECD countries.

Students scoring near the top of the scale (around 690 points) had at least a 50% chance of successfully completing tasks such as creating or using simple conceptual models to make predictions; analyzing scientific investigations in relation to experimental design; using data as evidence to evaluate alternative viewpoints or different perspectives; and communicating scientific arguments and/or descriptions in detail and with precision.

At an intermediate point on the scale (around 550 points), students could use scientific concepts to make predictions or give explanations; recognize questions that could be answered by scientific investigation and/or identify details of what is involved in scientific investigation; and select relevant information from competing data or chains of reasoning in drawing or evaluating conclusions.

Towards the lower end of the scale (about 400 score points), students could recall simple scientific factual knowledge (e.g., names, facts, terminology, simple rules) and use common science knowledge in drawing or evaluating conclusions.

VARIABLES ASSOCIATED WITH PERFORMANCE ON SCIENTIFIC LITERACY

In this section, a number of variables associated with performance on the assessment of scientific literacy are identified. Information on the variables was obtained from the Student Questionnaire which all students were invited to complete, and the School Questionnaire, which their principal teachers were asked to fill out. Although the study yielded data on a large number of variables, only five are described in this section. Three are student-level variables (gender; socioeconomic status; study of science), and two are school-level variables (school type and school designated disadvantaged status). Information on other variables associated with performance may be found in OECD (2001) and Shiel et al. (2001).

Student Gender

Significant gender differences in scientific literacy were observed in just four OECD countries. In Austria, Denmark, and Korea, male students performed significantly better than females, while in New Zealand, female performance was superior. In Ireland, female students had a higher mean score (516.9, SE = 4.17) than male students (510.7; SE = 4.23). However, the difference (6.2 points or less than one-tenth of a standard deviation) is not statistically significant. Across OECD countries, the average difference between male and female students is 0 (i.e., country differences cancelled themselves out).

Although the score of female students was 13.4 points higher than the score of male students at the 10th percentile in Ireland, the difference is not statistically significant. At the 90th percentile, male students scored 1.9 points higher than females. Again, the difference is not statistically significant.

Student Socioeconomic Status

A number of measures of socioeconomic status based on parents' occupational status and education were included in the study. The variable discussed here, the International Socioeconomic Index (ISEI) (Ganzeboom & Treiman, 1996), is based on the highest occupation of either parent, and constitutes a continuous scale. In Ireland, students below the 33rd percentile rank on the ISEI scale were categorized as 'low SES'; those between the 33rd and 67th percentiles as 'medium SES'; and those above the 67th percentile as 'high SES'.

The mean score on scientific literacy of high SES students (544.9; SE = 4.49) does not differ significantly from the mean score of medium SES students (528.6; SE = 5.08). However, medium SES students scored significantly higher than low SES students (489.0; SE = 4.49). The correlation between SES and performance is .31 ($p<.001$).

Study of Science

Eleven percent of students in Ireland indicated they had not studied science for the Junior Certificate examination. The mean score of students who had studied science (521.5; SE =3.16) is significantly higher than the mean score of students who had not (458.1; SE = 8.20). However, the mean PISA reading literacy scores of those who had studied science (521.2; SE = 8.20) is also significantly higher than the mean score of those who had not (474.2; SE = 3.16), suggesting that there may be other relevant differences between the two groups. Information on whether or not students in other OECD countries studied science was not available.

Students who had studied science at Higher level for the Junior Certificate examination (65% of students) had a mean score (548.2, SE = 2.69) that is significantly higher than the mean score of students who studied the subject at Ordinary level (445.6; SE = 5.07). The difference in mean scores between those who did not study science (458.1; SE = 8.20) and those who studied science at Ordinary level is not statistically significant.

School Type

Students attending secondary schools achieved a mean scientific literacy score (528.9; SE = 3.86) that is statistically significantly higher than the score of students attending community/comprehensive schools (505.7; SE = 6.10), while those in community/comprehensive schools achieved a mean score that is significantly higher than that of students in vocational schools (M = 475.7; SE = 7.16). The difference in performance between those attending secondary schools and those attending vocational schools is over one-half of an international standard deviation (52.9 score points).

School Designated Disadvantaged Status

Students attending schools designated as disadvantaged by the Department of Education and Science achieved a mean scientific literacy score of 477.6 (SE = 6.09). This contrasts with a mean score of 525.9 (SE = 3.47) for students in non-designated schools. The difference, almost one half of a standard deviation (48.8 points), is statistically significant.

Explaining Achievement in Scientific Literacy

A hierarchical linear model of the scientific literacy achievement of Irish students was developed to account for possible collinearity between individual variables, and to separate the effects of school- and student-level variables (Shiel et al., 2001). The model included two school-level variables (school type, school designated status). Student-level variables included socioeconomic status, student dropout risk, frequency of absence from school, completion of homework on time, current grade level, whether a student studied or did not study science, and an interaction between gender and number of books in the home. Even after controlling for the student-level variables, school type and school designated disadvantaged status made significant contributions to achievement. Further, student-level socioeconimic status explained variation in achievement over and above that explained by school designated status, confirming the contributions of both school- and student-socioeconomic status to achievement. Female students with more than 500 books in the home were expected to score 122 points (one-and-a-quarter standard deviations) higher than females with no books, while males with 500 books were expected to score 59.4 points (almost two-thirds of a standard deviation) higher than males with no books. The model explains 74.5% of between-school variance in achievement, and 34.1% of within-school variance.

LINKS BETWEEN PISA SCIENTIFIC LITERACY AND JUNIOR CERTIFICATE SCIENCE

In a detailed analysis of all 35 items included in the scientific literacy assessment reported in Shiel et al. (2001, Chapter 6), Irish science curriculum experts and teachers categorized each item in terms of the area of the Junior Certificate science syllabus into which it fell.[2] Almost one-third of items (31.4%) were judged to assess topics covered in the core component of the

2 The 1990 Junior Certificate science syllabus (Department of Education, 1990; Department of Education and Science, 1999) was in place at the time of the PISA assessment.

syllabus, mainly in biology/earth science rather than in physics or chemistry. An additional 22.9% of items were classified as tapping topics covered in the earth science option, which is taken by approximately two-thirds of students in the Junior Certificate science examination. Only one PISA science item was judged to assess topics in the category of materials science. None of the PISA items was identified in four Junior Certificate options (energy conversions, horticulture, food science, electronics). Over two-fifths of PISA items (42.9%) were judged not to be covered in the Junior Certificate science syllabus, though students may have had knowledge of them from their reading or study in other contexts (e.g., the greenhouse effect, genetics). In a separate analysis, 49% of PISA items were judged to assess concepts with which Higher-level science students would be unfamiliar, while 54% were judged to assess concepts that would be unfamiliar to Ordinary-level students.

In further analysis, over 90% of the scientific literacy items were judged to tap processes which Irish Junior Certificate students might be expected to be somewhat or very familiar with. Since the syllabus describes the development of scientific reasoning and problem-solving in a general sense, it was concluded that students studying science at either Higher or Ordinary level would be at least somewhat familiar with most of the reasoning processes in PISA. The complexity of scientific reasoning embedded in the remaining items was such that it was deemed unlikely that the process would have been taught or acquired at Junior Certificate level.

About four-fifths of scientific literacy items were rated as unfamiliar in terms of the contexts in which they were embedded. This conclusion was reached because students taking Junior Certificate science are considered not to be familiar with reading through lengthy texts, extracting relevant (scientific) information, and discarding redundant (non-scientific) information, skills that are necessary in the application of scientific knowledge and reasoning in PISA.

Given the substantial differences between the focus and approaches of PISA scientific literacy and Junior Certificate science, it is perhaps surprising that Shiel et al. (2001) found a strong correlation (.73) between performance on PISA scientific literacy and performance on the Junior Certificate science examinations taken by PISA students in 1999 and 2000. This finding suggests that, while the PISA assessment of scientific literacy and Junior Certificate science do not tap identical skills or content areas, there is a substantial overlap in the general abilities assessed.

CONCLUSION

The results of earlier international studies in which the science knowledge of post-primary students had been assessed might have led one to expect that Irish students would perform no better than average on PISA 2000 scientific literacy. Hence, one must ask why Irish students achieved a mean score in the assessment that was significantly higher than the OECD country average.

First, there is the observation that students in the sample of 15-year olds in PISA are spread across a number of grade levels (in Ireland, almost two-thirds are in third year, post-primary level). There is some evidence to suggest that countries with high levels of between-school variance in achievement, such as Germany and Austria, may implement institutional arrangements (such as the assignment of students to academic and vocational tracks, and the retention of lower-achieving students) which may not be conducive to high average levels of average achievement in an age-based sample, or to a narrow spread of achievement (see OECD, 2001).

Second, although there are clear differences between PISA and Junior Certificate science, there are also similarities. It may be the case, for example, that the relatively strong focus on biology/earth science in both PISA and the Junior Certificate syllabus/examination played to the strengths of Irish students notwithstanding the observation that some earth sciences items in PISA were not covered in the Junior Certificate syllabus. An assessment of scientific literacy that focused less on earth sciences, and more on physics and chemistry, might have disadvantaged Irish students to a greater extent, particularly those who did not study science at junior-cycle level.

Third, it seems reasonable to assume that the rather heavy reading load in some PISA items may have advantaged Irish students, who performed very well on the PISA assessment of reading literacy. Certainly, one would expect some overlap between the higher-order skills involved in reading comprehension and those involved in the scientific process, which was emphasized very much in the scientific literacy assessment. Reading processes assessed in PISA, such as critically evaluating or hypothesizing, dealing with concepts that are contrary to expectations, and using formal knowledge to evaluate a text, would all be expected to carry over to an assessment in which drawing on and evaluating scientific conclusions are stressed. Nevertheless, it is interesting to observe that the substantial difference in achievement in favour of female students on PISA reading literacy, in Ireland and in other countries, all but disappeared on PISA scientific literacy.

The finding that Irish students did considerably less well on PISA scientific literacy than students in the United Kingdom is worthy of further consideration.

First, it may be noted that the study of science is compulsory in England and Wales, at both primary and post-primary levels, whereas in Ireland it has only recently been formally introduced into the curriculum at primary level, and is not taken by about 11% of students – many of them attending all-girls schools – at junior cycle level (Task Force on the Physical Sciences, 2002). Second, all pupils in England and Wales are expected to sit a national assessment of science at the end of Key Stages 2 (age 11) and 3 (age 14), whereas just 90% of Irish students are assessed at national level in science during compulsory schooling, and this does not occur for most students until age 15. Third, curricula in science in England and Wales (see Qualifications and Curriculum Authority, 2000) stress the scientific method to a greater extent that the curriculum that was in place at junior cycle in Irish post-primary schools when PISA 2000 was administered (see Department of Education, 1990; Department of Education and Science, 1999). Fourth, there is some evidence that investigations (mini-projects) are more prevalent in science lessons in England and Wales than has been the case in Ireland, at least until the introduction of a revised Junior Certificate science syllabus in some schools in 2003. Watson and Wood-Robinson (1998), for example, provide descriptions of investigative work of the type offered in English schools that requires students to make decisions on their own or in groups about how investigations are to be carried out, and the ways in which procedures such as planning, observing, analyzing data, and evaluation methods are all incorporated into investigative work.

These observations would suggest that the revised Junior Certificate science syllabus (NCCA/Department of Education and Science, 2003b), which incorporates the PISA definition of scientific literacy, and is more contextually-based than its predecessor, could go some way towards improving scientific literacy. The NCCA/Department of Education and Science (2003a) have commented that ‘the most significant change in the revised syllabus is an increased emphasis on scientific investigation and on the application of science process skills in student activities’ (p. 2). This change is consistent with PISA. The revised Junior Certificate science syllabus also includes a shortening of the course to allow for more engagement with science applications and deeper understanding of science concepts. The NCCA (2000) has stated that in addition to acting as a source to guide syllabus development, the outcomes of future PISA assessments will be used to monitor the syllabus, and to make adjustments as appropriate. A syllabus for technology, a new subject, which incorporates many aspects of both the Science-Technology-Society approach and PISA (e.g., energy; technology, society, and the environment), is currently under development (NCCA, 2003).

The report and recommendations of the Task Force on the Physical Sciences (2002) is also supportive of the approach to science adopted by PISA. It noted, for example, that the importance attributed to scientific literacy in PISA (where it has equal status with reading literacy and mathematics) reflects the fact that science has become a primary objective of general education.

The assessment of scientific literacy in PISA 2006, which will be broader in scope than either PISA 2000 or PISA 2003, could provide some initial insights into the impact of the revised Junior Certificate syllabus on performance in scientific literacy, as many Irish students will have studied the scientific content and processes in the revised syllabus by that time.

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