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Overview and Rationale for the Study

This chapter provides an overview and rationale for this report, situating the study in the context of PISA research endeavours for both the past and the future. It describes early research on teaching and learning strategies and lays out the theoretical framework, key index and control variables which are derived for the examination of teaching and learning strategies and associated with higher mathematics performance.

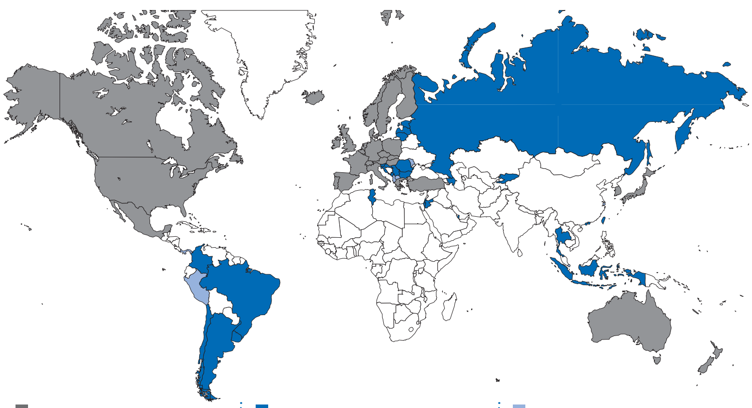
OVERVIEW OF PISA

The Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) began in 1997. Developed jointly by OECD member countries through the OECD's Directorate for Education, PISA measures the extent to which students are acquiring some of the knowledge and skills that are essential for full participation in today's knowledge society. PISA has an important role in the work of the OECD's Directorate for Education, which collects data and provides comparative indicators of education systems in OECD member and partner countries. PISA helps to highlight those countries which achieve both high performance and an equitable distribution of learning opportunities, and in doing so sets ambitious goals for other countries.

PISA's global span, regularity and test population are unique. More than 70 countries have taken part in one or more PISA surveys so far (see Figure 1.1). Beginning in 2000, these surveys have taken place at three-year intervals. The 2000 survey covered 32 countries and had reading as its major focus, with minor assessments in mathematics and science. The 2003 survey was carried out in 41 countries and had mathematics as its major focus, with minor assessments in reading, science and problem solving. The 2006 survey took place in 58 countries and focused on science, with minor assessments in reading and mathematics. All PISA surveys assess 15-year-old students, an age at which young adults are nearing the end of compulsory schooling in most countries.

In addition to the assessment instruments, PISA also includes detailed questionnaires to be completed by students and school principals. These questionnaires gather a variety of data on student backgrounds, behaviours and attitudes, student perceptions, teaching practices, school characteristics, the organisation of instruction and other factors that may be reported comparatively and used to help account for differences in achievement.

Figure 1.1 ■ **A map of PISA countries and economies**



OECD countries

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

Partner countries and economies in PISA 2006

Argentina
Azerbaijan
Brazil
Bulgaria
Chile
Colombia
Croatia
Estonia
Hong Kong-China
Indonesia
Israel
Jordan
Kyrgyzstan
Latvia
Liechtenstein
Lithuania
Macao-China
Montenegro
Qatar
Romania
Russian Federation
Serbia
Slovenia
Chinese Taipei
Thailand
Tunisia
Uruguay

Partner countries and economies in previous PISA surveys or in PISA 2009

Albania
Shanghai-China
Macedonia
Moldova
Panama
Peru
Singapore
Trinidad and Tobago

Source: OECD (2007).

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The OECD publishes the main results from each PISA survey in the year after the assessment has taken place. Participating countries also prepare individual country reports. In addition, the OECD publishes thematic reports drawing on the data from each PISA survey in order to present more detailed analysis of policy-relevant issues. This thematic report focuses on teaching and learning strategies and uses data from the PISA 2003 survey.

AIM AND AUDIENCE OF THIS REPORT

The analysis in this report may help clarify understanding of: the differences between teaching and learning practices in different countries, thus allowing countries to benchmark practices; the extent to which teaching and learning practices vary from school to school within each country, and the extent of the association between individual aspects of teaching and learning and better or worse performance in mathematics. The report will be useful for policy makers and stakeholders who need to understand better how their systems and school compare with those in other countries and economies who participated in PISA 2003. It may also provide insights for the design and implementation of educational policies aiming at improving the quality of education for all students.

In addition, this report may be of interest to teacher educators and officials within national and local educational authorities responsible for the professional development of teachers or programme development, as well as members of school boards and parent advisory bodies.

The report will also be useful to researchers concerned with the study of teaching and learning, particularly in identifying research questions that warrant follow-up through more intensive studies. Indeed, this report should be useful in helping to stimulate a new round of research designed to gain more detailed knowledge of teaching and learning strategies than is possible through large-scale survey methods.

BACKGROUND OF THIS REPORT

The report examines relationships among teaching strategies, student learning strategies and mathematics achievement, using data from the PISA 2003 survey. Figure 1.2 describes the PISA 2003 achievement scales in mathematics, reading and science. Because in 2003 mathematics was the focus of the PISA assessment and the questionnaires, this report concentrates on performance in mathematics.

The primary aim of this report is to identify instructional practices and learning strategies, both in general and within mathematics, that contribute both to increased achievement and to decreased variation in achievement. It also examines the degree to which such strategies are universal or context-specific and how these strategies may be related to the structure of school systems in different countries.

The overarching conceptual model for this report is the idea that the well-being of a modern society depends not only on capital and labour but also on the knowledge and ideas generated by individual workers. In particular, theory holds that economic benefits derive from investment in people, with education as the primary means of development of this human capital, so that educational expenditures are considered as investments (Sweetland, 1996). How then to maximise return on investment?

Long-term returns are beyond the scope of this report. Instead, it takes school achievement in mathematics as measured by PISA 2003 as a proximate outcome. Figure 1.3 gives a summary of overall student performance in different countries on the PISA 2003 mathematics scale, presented

Figure 1.2 ■ **Summary of the assessment areas covered in PISA 2003**

Assessment area	Mathematics	Science	Reading
Definition and its distinctive features	"The capacity to identify and understand the role that mathematics plays in the real world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen" (OECD, 2003e). Related to wider, functional use of mathematics, engagement requires the ability to recognise and formulate mathematical problems in various situations.	"The capacity to use scientific knowledge, to identify scientific 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, 2003e). Requires understanding of scientific concepts, an ability to apply a scientific perspective and to think scientifically about evidence.	"The capacity to understand, use and reflect on written texts in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society" (OECD, 2003e). Much more than decoding and literal comprehension, reading involves understanding and reflection, and the ability to use reading to fulfil one's goals in life.
"Content" dimension	Clusters of relevant mathematical areas and concepts: • quantity; • space and shape; • change and relationships; and • uncertainty.	Areas of scientific knowledge and concepts, such as: • biodiversity; • forces and movement; and • physiological change.	The form of reading materials: • "continuous" materials including different kinds of prose such as narration, exposition, argumentation; and • "non-continuous" texts including graphs, forms, lists.
"Process" dimension	"Competency clusters" define skills needed for mathematics: • reproduction (simple mathematical operations); • connections (bringing together ideas to solve straightforward problems); and • reflection (wider mathematical thinking). In general these are associated with tasks of ascending difficulty, but there is overlap in the rating of tasks in each cluster.	The ability to use scientific knowledge and understanding, to acquire, interpret and act on evidence: • describing, explaining and predicting scientific phenomena; • understanding scientific investigation; and • interpreting scientific evidence and conclusions.	Type of reading task or process: • retrieving information; • interpreting texts; and • reflection and evaluation of texts. The focus of PISA is on "reading to learn", rather than "learning to read", and hence students are not assessed on the most basic reading skills.
"Situation" dimension	Situations vary according to their "distance" from individuals' lives. In order of closeness: • personal; • educational and occupational; • local and broader community; and • scientific.	The context of science, focusing on uses in relation to: • life and health; • the Earth and the environment; and • technology.	The use for which the text constructed: • private (*e.g.*, a personal letter); • public (*e.g.*, an official document); • occupational (*e.g.*, a report); • educational (*e.g.*, school related reading).

Source: OECD (2004), *Learning for Tomorrow's World: First Results from PISA 2003*, OECD, Paris.

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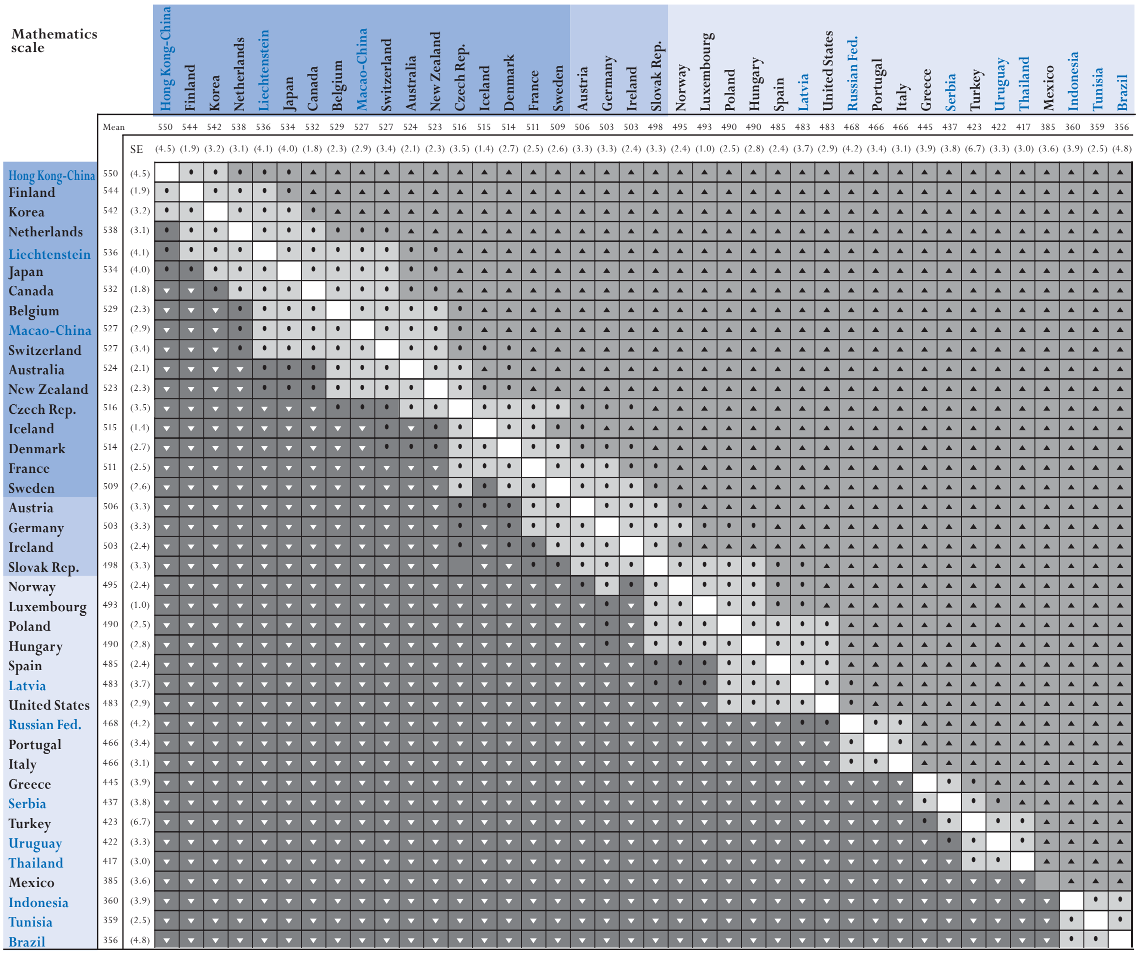
in terms of the mean student score. When interpreting mean performance, only those differences between countries that are statistically significant should be taken into account. Figure 1.3 therefore shows those pairs of countries where the difference in their mean scores is sufficient to say with confidence that the higher performance by sampled students in one country holds for the entire population of enrolled 15-year-olds.

Figure 1.3 ■ Multiple comparisons of mean performance on the mathematics scale



Range of rank*

		Hong Kong-China	Finland	Korea	Netherlands	Liechtenstein	Japan	Canada	Belgium	Macao-China	Switzerland	Australia	New Zealand	Czech Rep.	Iceland	Denmark	France	Sweden	Austria	Germany	Ireland	Slovak Rep.	Norway	Luxembourg	Poland	Hungary	Spain	Latvia	United States	Russian Fed.	Portugal	Italy	Greece	Serbia	Turkey	Uruguay	Thailand	Mexico	Indonesia	Tunisia	Brazil
OECD countries	Upper rank		1	1	1		1	3	3		3	6	6	8	10	9	10	10	11	12	14	15	17	18	18	18	21		21		25	25	27		28			29			
	Lower rank		3	4	6		9	7	9		10	10	10	15	14	15	16	17	18	19	19	22	22	22	24	24	24		24		26	26	27		28			29			
All countries	Upper rank	1	1	1	1	1	2	4	4	5	5	8	8	10	13	12	13	13	14	15	16	18	20	21	21	21	24	23	24	28	29	29	32	32	33	34	34	37	38	38	38
	Lower rank	5	5	6	8	11	12	10	11	13	13	13	13	18	17	18	19	20	21	22	21	25	25	25	27	28	28	29	28	31	31	31	33	33	36	36	36	37	40	40	40

*** Because data are based on samples, it is not possible to report exact rank order positions for countries. However, it is possible to report the range of rank order positions within which the country mean lies with 95 per cent likelihood.**

Instructions:

Read across the row for a country to compare performance with the countries listed along the top of the chart. The symbols indicate whether the average performance of the country in the row is significantly lower than that of the comparison country, significantly higher than that of the comparison country, or if there is no statistically significant difference between the average achievement of the two countries.

Without the *Bonferroni adjustment:*
- Mean performance statistically significantly higher than in comparison country.
- No statistically significant difference from comparison country.
- Mean performance statistically significantly lower than in comparison country.

With the *Bonferroni adjustment:*
- ▲ Mean performance statistically significantly higher than in comparison country.
- • No statistically significant difference from comparison country.
- ▽ Mean performance statistically significantly lower than in comparison country.

- Statistically significantly above the OECD average
- Not statistically significantly different from the OECD average
- Statistically significantly below the OECD average

Source: OECD PISA 2003 database.

In Figure 1.3, a country's performance relative to that of the countries listed along the top of the figure can be seen by reading across each row. The colour-coding indicates whether the average performance of the country in the row is either lower than that of the comparison country, not statistically different, or higher. When making multiple comparisons, *e.g.* when comparing the performance of one country with that of all other countries, an even more cautious approach is required, and only those comparisons that are indicated by the upward or downward pointing symbols should be considered statistically significant for the purpose of multiple comparisons. Figure 1.3 also shows which countries perform above, at or below the OECD average. It is not possible to determine the exact rank order position of countries in the international comparisons (see Box 2.1 in OECD, 2004 for details). However, Figure 1.3 shows, with 95% probability, the range of rank order positions within which the country mean lies, both for the group of OECD countries and for all countries that participated in PISA 2003.

Mean performance scores are typically used to assess the quality of schools and education systems. Mean performance however does not provide a full picture of student performance and can mask significant variation within an individual class, school or education system.

Achievement as measured by PISA has an impact on access to higher education and thus ultimately on economic advantage and other longer-term outcomes contributing to the well-being of both the individual and society. *Pathways to Success* (OECD, 2010), offers an example and shows for example that top performing Canadian students in PISA are twenty times more likely to access university than those performing at the bottom.

PISA results have shown that students' socio-economic background is a strong predictor of achievement (OECD, 2001; OECD, 2004; OECD, 2007). In this report, socio-economic background is a control variable in most of the models developed, to ensure that teaching and learning strategy effects are treated independently of socio-economic effects. Furthermore, the productivity model used may not be especially helpful in providing insights into the policies, strategies and practices that might allow for higher achievement and greater equity in achievement, despite the utility of such a model as an overarching way of establishing the importance of high achievement. However, theory and research on teaching and learning can prove helpful, as discussed below.

DEFINITION AND RELEVANCE OF TEACHING AND LEARNING STRATEGIES

Teaching strategies refer to a broad range of processes, from the organisation of classrooms and resources to the moment-by-moment activities engaged in by teachers and students to facilitate learning. Student learning strategies refer to cognitive and meta-cognitive processes employed by students as they attempt to learn something new. PISA measures teaching and learning strategies using a variety of questionnaire items, which in turn are combined and scaled to yield a number of composite or index variables representing broad constructs. Examples of these constructs are disciplinary climate, teacher-student relations, memorisation strategies and time spent on various learning activities. Further, PISA 2003 gears these measures specifically towards the learning of mathematics. The recent publication of the first results from the OECD Teaching and Learning International Survey (see Box 1.1) adds considerably to the knowledge of differences in the uses of these strategies across participating countries, and affirms the importance of investigating these strategies. Although TALIS does not examine the relationship of these strategies to student learning, this would be possible using data from subsequent cycles of PISA (*e.g.* PISA 2006 and 2009).

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Box 1.1 ■ The OECD Teaching and Learning International Survey

The OECD Teaching and Learning International Survey (TALIS) is the first international survey in which the major focus is on the learning environment and the working conditions of teachers in schools. TALIS offers an opportunity for teachers and school principals to provide input into education analysis and policy development, by means of the issues examined in the survey. Cross-country analysis from TALIS will allow individual countries to identify other countries facing similar challenges and to learn from other policy approaches. The main study took place in 2007-08 and an initial report was published in 2009 (OECD, 2009). First results from TALIS appear below:

Creating effective teaching and learning environments

In most countries, the large majority of teachers are satisfied with their jobs and consider that they make a significant educational difference to their students. Teachers are also investing in their professional development, both in terms of time and often also in terms of money, an investment which goes hand in hand with a wider repertoire of pedagogic strategies used in the classroom.

Better support for effective teaching is needed through teacher appraisal and feedback. The generally positive reception by teachers of the appraisal and feedback which they receive on their work indicates a willingness in the profession to move forward in this area.

TALIS highlights better and more targeted professional development as an important lever for improvement in teacher effectiveness. Relatively few teachers participate in the kinds of professional development which they find have the largest impact on their work, namely programmes leading to a qualification, and individual and collaborative research.

The hardest issues to resolve relate to the actual improvement of teaching practice. Teachers in most countries report using traditional practices aimed at transmitting knowledge in structured settings much more often than they use student-oriented practices, such as adapting teaching to individual needs.

TALIS suggests that effective school leadership plays a vital role in teachers' working lives and that it can make an important contribution to shaping the development of teachers. In schools where strong instructional leadership is present, TALIS shows that school principals are more likely to use further professional development to address teachers' weaknesses as identified in appraisals.

The close associations that TALIS shows between factors such as a positive school climate, teaching beliefs, co-operation between teachers, teacher job satisfaction, professional development, and the adoption of a range of teaching techniques provide indications that public policy can actively shape the conditions for effective learning. At the same time, the fact that much of the variation in these relationships lies in differences among individual teachers, rather than among schools or countries, underlines the need for individualised and targeted programmes for teachers to complement the whole-school or system-wide interventions that have traditionally dominated education policy.

Source: OECD (2009), *Creating Effective Teaching and Learning Environments: First Results from TALIS*.

In their well-known synthesis of factors influencing achievement, Wang *et al.* (1993) put forward the concept of proximity as a way of thinking about the relative effects of various factors. The general hypothesis is that, proximal factors, or those which touch the day-to-day lives of students most closely, are likely to be more influential than more distal factors, such as administrative characteristics of the education system at the national level. For example, classroom management, metacognitive processes, cognitive processes, home environment, parental support and student-teacher social interactions show stronger relationships to achievement than broad state- and district-level educational policies. This point is of crucial importance because it suggests that broad policy initiatives are likely to result in improved learning only if translated into change at the individual teacher or student level.

Among the many factors that influence scholastic proficiency, teaching and learning strategies are second only to home circumstances in their proximity to the day-to-day activities of students and hence in their potential to influence performance directly. Teaching strategies also change through educational policy initiatives and through teacher education and professional development. Determining which teaching and learning strategies are most effective in improving overall performance and reducing disparities in performance is one of the primary functions of educational research and one of the most direct ways in which policy decisions can influence learning.

From a policy perspective, it is also useful to consider briefly how strategies proved to be successful may be implemented. It is important to distinguish those that can be put into practice through teacher education from professional development or other policy initiatives within the control of educational jurisdictions, as well as to distinguish those that can be implemented at relatively low risk or low cost from those with significant risks or cost implications. Policy decisions based on relatively weak evidence can be justified if the risks are small and the costs are low, but not under other circumstances.

EARLY RESEARCH ON TEACHING AND LEARNING STRATEGIES

Although one might expect research on teaching strategies and on learning strategies to converge, the two tend largely to follow separate paths. Much early work on teaching strategies follows a relatively simple "process-product" model, under which the primary focus is on correlations between classroom processes and student achievement. The archetypal study under this model is a small-scale classroom observational study which categorises and correlates various classroom processes with measures of achievement. During the 1970s, a number of relatively large-scale quasi-experimental field studies took this approach (*e.g.* Brophy and Evertson, 1974; Stallings and Kaskowitz, 1974; Clark *et al.,* 1979). However, research of this nature has declined in recent years.

Dunkin and Biddle's seminal volume *The Study of Teaching* (1974) summarised much of the early research on teaching. Other major syntheses of this work appeared in the third edition of the *Handbook of Research on Teaching* (Wittrock, 1986, particularly the chapters by Shulman, Brophy and Good, Rosenshine, and Stevens and Doyle). Dunkin and Biddle present a model for the study of teaching that extends beyond the dominant process-product model to include what the authors call presage and context variables. In this model, both these categories of variables have only indirect influences on outcomes. Shulman's *Handbook* chapter attempts to go beyond the process-product model to present a synoptic model that includes teacher and student backgrounds, curriculum content, classroom processes and the various contexts and agendas that impinge on teaching and

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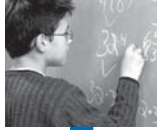

learning. The intellectual and social/organisational transactions which mediate teaching to produce learning are a major component of Shulman's model. This concept of mediation forms the basis for a broader approach that can help integrate research on teaching and learning.

Early research on teaching, especially that based on the process-product model, tends to be largely atheoretical, consisting essentially of a search for correlates of teaching variables with achievement. Research on learning has traditionally had a more theoretical orientation than research on teaching, and has grown out of either behavioural or cognitive psychology. Early studies in the behavioural tradition tend to be concerned with memory or conditioning, under a simple stimulus-response model. What goes on in the learner's mind between the stimulus and the response is not part of the model. Cognitive studies vary widely and include developmental work in the Piagetian tradition, problem solving, and learning by discovery, as well as meta-cognitive strategies, and other aspects of learning that can be identified with "active learning". Within the constructivist framework, more recent work may be considered as a logical extension of the cognitive approach. Such studies explore, at least implicitly, the intervening events between the stimulus and response or between the process and product.

Research on teaching and learning is beginning to converge in the mediating process and constructivist approaches. From this more integrated perspective, one may argue that students construct knowledge through a complex process of interaction with all of the features of their environment, including their home, peer group and school, as well as other sources of influence. Educational policy aims primarily at influencing the school environment, while other influences, such as home circumstances, may be mediated by broader social or economic policies. Nevertheless, educational policy may be designed to improve the effects of other environmental influences, particularly negative ones. Indeed, the whole concept of improving equity in educational achievement (not just in educational opportunities) may be said to stem from the need to overcome adverse influences outside the school.

Research on teaching and on learning is also converging to some degree in studies of the impact of self-concept, motivation, attention and meta-cognitive processes (strategies for learning). The work of Cronbach and Snow (1977) and others on aptitude-treatment interactions is an example of this convergence, specifically of the idea that teaching strategies can or should match learning styles. However, this research seems to offer little guidance on how such matches can be made under classroom conditions.

The well-known time-based model originally proposed by Carroll (1963) captures the notion that teaching influences learning by incorporating into the core model the components of opportunity to learn, time allocated by the teacher and quality of instruction. This model connects further with a broad approach to teaching and to educational policy in its extension by Bloom (1981) to the concept of "mastery learning". In an attempt to address directly the issue of equity in learning, Bloom proposes that the time allocated to accomplish a task vary sufficiently in order to allow almost all students to achieve specified learning outcomes. Putting this into practice, of course, requires significant variation in both school organisation and teaching strategies, to an extent that it is difficult to find examples of large-scale implementation of mastery learning, despite its strong research support.

THE CARROLL MODEL AS A THEORETICAL FRAMEWORK

Many of the components of teaching and learning theories derive from the Carroll model (OECD, 2004). Indeed, although often cited as simply an argument for increasing time allocations, Carroll's formulation actually captures important elements of the teaching and learning process, such as quality of teaching, opportunity to learn, and student ability within the time framework. This model therefore warrants some elaboration.

In his original 1963 article in the *Teachers College Record,* Carroll sets out to propose a mathematical formulation of the common-sense notion that learning takes place in a time framework. The mathematical formulation of the Carroll model may be stated as:

> The degree of learning or achievement (*L*) is a function of the ratio of the time actually spent on learning (*Tsl*) to the time needed to learn (*Tnl*), or

$$L = f(Tsl/Tnl)$$

Although mathematical in form, the model is essentially a conceptual one because the detailed nature of the function is unspecified in Carroll's original formulation. For example, it is not clear if the relationship is linear or if there are saturation, fatigue or other effects that might limit the value of spending more time on learning. Obviously, at some level, such limits exist. However, in practical terms, it is not at all simple to determine when individuals begin to approach these limits.

Although time is the central construct of Carroll's model, more specific components, which relate to teaching and learning, influence both time spent and time needed. The value of the model for studies such as this one derives from these components. Three components cover learner characteristics: ability, aptitude and perseverance. Ability refers to the underlying mode or style of learning relative to a particular task and hence affects time needed. Aptitude can be defined as the time needed to achieve mastery of a particular task. Perseverance is simply the amount of time the learner is willing to devote to the task. Two other components are characteristic of the learning environment: opportunity to learn and quality of instruction. Opportunity to learn is best thought of as limited by the total time available, or allocated time; quality of instruction influences time needed. Students exposed to low-quality instruction would be expected to require more time to learn than those exposed to higher-quality instruction. Although generally believed to be of crucial importance, quality of instruction is one of the most elusive constructs in the model because it involves a complex interplay of factors including teacher qualifications, resources and the nature of the moment-by-moment interactions that occur between teacher and students. Carroll's model itself offers no specific guidance as to what constitutes high- or low-quality instruction. Much of the empirical work on teaching strategies over the past few decades may be seen as a search for the essential elements that define high-quality instruction.

Caroll revisited his original 1963 model in a 1989 retrospective. He concludes that optimising academic learning time is one of the most important factors in improving student achievement. More recent reviews by Scheerens and Bosker (1997) and Marzano (2003) reinforce this conclusion. However, the problem remains of how this optimisation can be accomplished, especially within the overall constraints of conventional school years or days.

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The Carroll model has been adopted to make a case for more learning time (*e.g.* Wiley and Harneschfeger, 1977) or for organising schools on a variable-time basis, in which students who need more time are given more time (*e.g.* Bloom, 1976). In practice, however, school systems are not organised explicitly in either of these ways and it is difficult to see how such changes could be implemented on a large scale within any jurisdiction. For the most part, any variations in learning time must fit within the global constraints of the school day and year by optimising use of the total time available within the school, trading off time on one subject against that spent on others, or adding to this time through appropriate out-of-school activities such as homework. The present study shifts the focus from looking directly at time to examining teaching and learning strategies that might help optimise time spent and reduce time needed. This approach provides a powerful heuristic for policy because it allows policy makers to think in terms of a broad factor over which they may have some influence.

A number of factors associated with effective mathematics instruction and effective student learning strategies also form part of the time model. These factors include time on task, homework, opportunity to learn, time lost on non-instructional activities, quality of curriculum and instructional material and quality of assessment practices. Many of the relationships identified are supported by recent research syntheses, particularly those by Wang *et al.* (1993), Scheerens and Bosker (1997) and Marzano (2003) and by a number of reports based on PISA 2000 (*e.g.* Kirsch *et al.,* 2002; Artelt *et al.,* 2003).

The Wang *et al.* synthesis is particularly useful because it supports the hypothesis that proximal variables are more closely associated with learning than distal variables. More specifically, the variables showing the strongest relationships with achievement are those in the areas of classroom management, meta-cognitive processes, cognitive processes, home environment and parental support, and student-teacher social interactions. Motivation, peer group influences, quantity of instruction, classroom climate, and other proximal variables also receive high rankings (Wang *et al*, 1994). This work also shows that variables related to broad state- and district-level educational policies are less influential. However, the Wang *et al.* formulation does not consider the possibility of indirect influences of such factors, through their more direct impact on instructional processes.

Some of the more recent syntheses have helped identify more specific positive influences on achievement. For example, Scheerens and Bosker (1997) produce a ranking of school factors found to have positive influences on learning. These include time, monitoring, pressure to achieve, parental involvement and content coverage. The type of school climate most likely to enhance learning is one with an orderly atmosphere, rules and regulations, and good student conduct and behaviour. Similarly, effective classroom management strategies include direct instruction, monitoring student progress and a positive attitude to work.

Most of the studies in the various syntheses have been small-scale and local in scope and typically cover only a few of the many variables that might be expected to influence learning. Because of the large number of variables available and the wide range of contexts used, large-scale surveys such as PISA offer the potential to uncover more robust relationships, as well as to investigate the influence of variations in context on the results. The extensive coverage of the PISA database allows the analysis of particular factors that may positively or negatively relate to students' achievement, while also taking account of other factors that may cloud or complicate this relationship.

It must also be noted that large-scale surveys have shortcomings in other ways. In particular, only partial information can be gathered on teaching strategies because of the limitations of self-report questionnaires, the inability to sample adequately at the school or classroom level and the cross-sectional nature of these studies. A particular limitation of PISA in this respect is the absence of a teacher questionnaire in both the 2000 and 2003 surveys. Such an instrument would make it possible to capture much more detailed information on instructional practices and opportunity to learn than the student and school questionnaires permit.

However, cross-sectional studies are unable to capture instructional strategies occurring over the student's whole school career. The data on teaching strategies are thus less stable and cumulative than variables on home environment or student characteristics, for example, which reflect the individual's life experience. The correlations, which are the basis of most of the analysis in this report, are therefore likely to be weaker for teaching and learning strategies than for student background variables and weaker than would be expected based on the proximal-distal hypothesis. This limitation of the data is less of a problem for student learning strategies than for teaching strategies, as one might expect the particular learning strategies used by students to be products of their long-term exposure to a particular school or school system.

PISA did not collect information on all components of interest within the Carroll model and its extensions. For example, it did not examine ability or opportunity to learn. In addition, this report does not correlate all of the measures collected in PISA with achievement. For these reasons, and to avoid having overly cumbersome models, the report provides two stages of initial selection. First, the report uses only those variables showing consistent patterns of correlation with mathematics achievement across countries. Second, the report drops variables from successive iterations of the main models if they show few significant effects in the presence of other variables in the model. Note that the report retains a few variables judged to be of particular policy relevance even if they do not meet these criteria, as it may be helpful to indicate explicitly that these variables have minimal effects.

KEY TEACHING AND LEARNING VARIABLES

The PISA database contains observed variables representing responses by students and school principals to all questionnaire items, as well as overall assessment results. Some of the questionnaire items ask for facts (*e.g.* "Do you have a study desk at home?"). Others require estimates of time or other factors (*e.g.* "How many hours per week do you spend on homework?"). Finally, some items are intended to solicit opinions (*e.g.* "I do mathematics because I enjoy it"). These last items usually provide a four-point scale for response, from "strongly agree" to "strongly disagree" or another similar scale, such as degree of confidence.

During the initial design and analysis, many of the questionnaire items combine to form a number of derived or index variables, representing broader underlying constructs. For example, the *index of disciplinary climate in mathematics lessons* derives from student responses to five items on the student questionnaire concerning the extent to which students did not listen to the teacher, could not work well, lost time at the start of each lesson by not working or quietening down, and reported noise and disorder. For the most part, index variables representing teaching and learning strategies are the ones of most interest here. Although more abstract than the observed variables, they are more efficient in building models because they capture more information in a single scale and because

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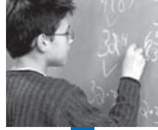

Table 1.1
Key teaching and learning variables

Variable	Scale/unit	OECD average	Definition/illustrative questionnaire item
Total homework time	Hours per week	5.89	
Mathematics homework time	Hours per week	2.43	
Tutoring	Dichotomous (1,0)	*[1]	Student being tutored or not.
Out-of-class lessons	Dichotomous (1,0)	*	Student taking out-of-class lessons or not.
Memorisation/ rehearsal strategies	Standard score	0	When I study mathematics, I try to learn the answers to problems off by heart.
Elaboration strategies	Standard score	0	When I am solving mathematics problems, I often think of new ways to get the answer.
Control strategies	Standard score	0	When I study mathematics, I start by working out exactly what I need to learn.
Competitive learning preference	Standard score	0	I make a real effort in mathematics because I want to be one of the best.
Co-operative learning preference	Standard score	0	I do my best work in mathematics when I work with other students.
Teacher support	Standard score	-0.01	The teacher helps students with their learning.
Student-teacher relations	Standard score	0.01	If I need extra help, I will get it from my teachers.
Disciplinary climate	Standard score	0.01	Students don't listen to what the teacher says.
School average disciplinary climate	Standard score	0	Disciplinary climate aggregated to the school level.

scaling the index variables in a certain way more closely meets the underlying assumptions of the models. However, particularly at the descriptive stage, values for observed variables have also been reported because these are more intuitively clear and more directly descriptive of behaviour. For example, one may interpret the observed variable "noise and disorder in the classroom" in a straightforward way through response frequencies to the categories used in the questionnaire.

The teaching and learning variables selected for consideration in the final models are set out in Table 1.1. The actual questions that make up many of the index variables used, as well as the response proportions for these questions, appear in much greater detail in Chapter 3 of *Learning for Tomorrow's World: First Results from PISA 2003* (OECD, 2004).

CONTROL VARIABLES

The report treats student socio-economic background, attitudes and motivations as antecedent conditions, which should be adjusted for in developing models designed to investigate the effects of teaching and learning strategies on achievement. This report recognises that the direction of causality is problematic in models based on correlational methods and that other analytical approaches could treat attitude or engagement variables either as outcomes or as attributes that might actually be taught as indirect ways of improving achievement. For example, it is commonly argued that high self-concept is a by-product of high achievement or that teaching should be designed to ensure that student self-concept is not damaged. These issues, though interesting in their own right, are not addressed here.

The control variables used in the models developed for this report appear in Table 1.2. Again, further details on the index variables appear in *Learning for Tomorrow's World: First Results for PISA 2003* (OECD, 2004).

Table 1.2
Control variables

Variable	Scale/unit	OECD average	Definition/illustrative questionnaire item
Socio-economic status			
Highest occupational status of parents	Standard score	48.79	Scaled score from student-reported parent occupations.
Highest educational level of parents		4.19	6-point scale of standard international educational levels (based on ISCED) from student-reported educational level of parents.
Books in home		3.50	6-point questionnaire scale, 0-10=1, more than 500=6
Attitudes			
Interest and enjoyment of mathematics	Standard score	0	I look forward to my mathematics lessons.
Sense of belonging in school	Standard score	0	School is a place where I feel like I belong.
Mathematics anxiety	Standard score	0	I get very nervous doing mathematics problems.
Perceptions of mathematics competency			
Mathematics self-efficacy	Standard score	0	How confident do you feel about having to do … (selected mathematics tasks)?
Mathematics self-concept	Standard score	0	I get good marks in mathematics.
Motivation			
Instrumental motivation	Standard score	0	I will learn many things in mathematics that will help me get a job.
School variables			
School size	100 students	5.36	Total school enrolment/100.
School average highest occupational status of parents		46.98	Highest occupational status of parents aggregated to school.

OTHER VARIABLES

As already indicated, the report excludes some variables identified in the original formulation from the main models used here because in general they show non-significant correlations with achievement or small effects in early iterations of the model. Many of the school-level questionnaire variables are in this category. Some examples of these variables are those around streaming and grouping and assessment practices. The report retains total instructional time and mathematics instructional time through to the final model but these show non-significant effects throughout. Because they are useful indicators of differences between countries and between schools within countries, the report discusses some of these variables as part of the descriptive analysis presented in Chapter 2. These variables are also of policy interest and show significant effects in other studies.

OVERVIEW OF THE ANALYTICAL APPROACH

This report follows a two-stage analytical approach. Chapter 2 reports on the first stage. It includes a descriptive/comparative analysis of mathematics teaching and learning that describes how mathematics is taught in different countries, examines variations across schools within countries, and, based on this analysis, presents a broad profile of commonalities and differences in mathematics teaching and learning. While limited in their ability to provide explanations for differences in mathematics teaching methodology, the Chapter 2 results inform policy makers in individual countries

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as to how their situation might differ from that of other countries in terms of consistency or variety among schools.

Chapter 3 reports on the second stage. This stage requires the construction of a comprehensive two-level (student and school) prediction model of the factors influencing mathematics achievement. Primary emphasis is on the teaching and learning strategy variables described in Table 1.1. Following the temporal logic described earlier, the control variables as given above in Table 1.2 are antecedents to teaching and learning and hence entered into the model in stages, before the teaching and learning variables. This approach allows the predictive power of the model to be determined as groups of variables enter in stages. Nevertheless, the basis of the final reporting of the effects of each of the main variables is the full model. While this limits the ability to examine in detail the joint and mediating effects of variables, the full model gives a more complete picture of the real world of teaching and learning than do the intermediate models. The intermediate models may be of more theoretical interest while the full model is of more interest from a policy perspective. The report then examines mediating effects in part by comparing effects using the full model with those for each variable used independently (a bivariate model).

Further details on the analytic procedures used are given at the beginning of Chapters 2 and 3.

Note

1 The asterisks in Table 1.1 indicate where only proportion information is available.

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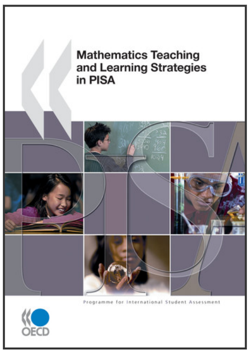

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