CONTEXTUAL FRAMEWORK FOR PISA 2006

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INTRODUCTION

1. PISA seeks to provide policy-relevant information on 15-year-old students’ literacy in Reading, Mathematics and Science, with scientific literacy as the major assessment domain in 2006. Through the additional collection of information on students and their educational environments, PISA 2006 should allow the identification of social, cultural, economic and educational factors that are associated with student performance. Using the data from questionnaires, analyses linking contextual information with student outcomes will allow PISA to address differences:
   - between countries in the relationships between student level factors (such as gender and social background) and outcomes;
   - across countries in the relationships between school level factors and outcomes;
   - in the proportion of variation in outcomes between (rather than within) schools, and differences in this value across countries;
   - between countries in the extent to which schools moderate or increase the effects of individual-level student factors and student outcomes;
   - in education systems and national contexts that are related to differences in student outcomes across countries; and,
   - in any or all of these relationships over time.

2. This document elaborates the framework that led to the implementation of the PISA 2006 context questionnaires. This contextual framework will:
   - outline the development process of the PISA 2006 context questionnaires;
   - describe the conceptual structure used to guide the development of the contextual instruments;
   - elaborate upon the main areas of research focussed upon in the PISA 2006 contextual instruments, including concise state of the art literature reviews on the research area.

3. The purpose of this document is to assist researchers and users of research relating to PISA 2006 in understanding the rationale for the contextual variables in the database. Furthermore, the elaborations are intended to assist those unfamiliar with the particular research areas by providing a useful set of references to the relevant literature.

4. Annotated versions of the international English versions of the Student, School and Parent Questionnaires administered in the main survey of PISA 2006 are appended.
DEVELOPMENT OF THE PISA 2006 CONTEXTUAL INSTRUMENTS

5. In its Call for Tender for PISA 2006, the PISA Governing Board (PGB) established the main policy issues it sought to address in the third cycle of PISA. In particular, the PGB required PISA 2006 to collect a set of basic demographic data as a core component that replicates key questions from the previous cycles. The PGB also requested that PISA 2006 address issues related to important aspects of students’ attitudes regarding science, information about students’ experience with science in and out of school, motivation, interest in and concern about science and engagement with science-related activities.

6. Since the impact of out-of-school factors was considered of particular interest in a cycle where Science was the major domain, the PGB recommended the inclusion of a Parent Questionnaire as an optional instrument, in order to collect additional information on issues such as science-related parental expectations and attitudes, as well as possible family investment in activities aimed at developing students’ interest and learning in scientific areas.

7. The PISA 2006 Project Consortium undertook the operationalisation of these goals with the assistance of a variety of experts. In particular, a Questionnaire Expert Group (QEG) was established, consisting of experts from a variety of research backgrounds and countries. The Consortium and the QEG worked together to develop the Contextual Framework for PISA 2006 and the contextual instruments. Other experts were consulted where appropriate, especially some members of the Science Expert Group.

8. An initial step was the development of an organising structure which allowed the mapping of the PGB’s priority policy issues to the design of PISA 2006. The development of this conceptual structure is outlined in the next section of this framework.

9. One objective of the conceptual structure was to facilitate the development and choice of research areas that combine policy relevance effectively with the strengths of the PISA design. To aid this, a set of criteria established by the INES Network A was used:

- First, the research area must be of enduring policy relevance and interest. That is, a research area should have policy relevance, capture policy-makers’ attention, address their needs for data about the performance of their educational systems, be timely, and focus on what improves or explains the outcomes of education. Further, a research area should be of interest to the public, since it is this public to which educators and policy-makers are accountable.
- Second, research areas must provide an internationally comparative perspective and promise significant added value to what can be accomplished through national evaluation and analysis. This implies that research areas need to be both relevant (i.e. of importance) and valid (i.e. of similar meaning) across countries.
- Third, there must be some consistency in the approach of each research area with PISA 2000 and PISA 2003.
- Fourth, it must be technically feasible and appropriate to address the issues within the context of the PISA design. That is, the collection of data about a subject must be technically feasible in terms of methodological rigour and the time and costs (including opportunity costs) associated with data collection.

10. The resulting research areas were:

- Student’s Engagement in Science
- Science Attainment and the Labour Market
- Teaching and Learning Science
- Scientific Literacy and Environment
- Organisation of Educational Systems
Detailed discussions of these research areas, including brief literature reviews, were elaborated by experts in these particular areas. These elaborations follow in the subsequent chapters of this framework document.

11. From the theoretical bases of each research area, as elaborated, a large number of constructs were defined and their measurement operationalised through obtaining or writing questionnaire items (often in item batteries to form scales).

12. Empirical data used to help establish the validity and reliability of the resulting contextual instruments came initially from a pilot of student questions in four countries in four languages (English, German, French and Japanese) in 2004. Then, in 2005, data were gathered from a full scale Field Trial of Student, School and Parent Questionnaires in each of the 58 participating countries in over 40 languages. The Field Trial was able to facilitate the investigation of a large number of student questionnaire items through the use of a rotational design of four student questionnaire forms. Having more than one questionnaire form also allowed the trialling of items with alternative wording or different response formats (for example, Likert-type and dichotomous response options).

13. Empirical analyses included the examination of:
   - the frequency of missing values by country;
   - the magnitude and consistency of item-total score correlations for each scale, by country;
   - the magnitude and the consistency of scale reliability (Cronbach’s Alpha), by country;
   - the magnitude and consistency of correlations with each scale and Science achievement as determined in the PISA Field Trial science test, by country;
   - Confirmatory Factor Analyses to determine construct validity and reliability of each scale across the pooled sample;
   - Item Response Theory analyses to determine item fit across the pooled sample.

14. In addition to the empirical analyses, the choice of items, item format and wording was informed by:
   - feedback from National Project Managers
   - feedback from linguistic experts
   - discussions with the Questionnaire Expert Group
   - discussions with members of the Science Expert Group
   - consultation with Science Forum nominees of the PISA Governing Board;
   - consultation with the OECD secretariat; and
   - direction from the PISA Governing Board.

15. Finally, in October 2005 a large and comprehensive set of potential items and topics was provided to the PISA Governing Board. From this set, the PGB indicated priority areas for investigation. Equivalent international source versions were also provided in English and French.

CONCEPTUAL STRUCTURE

16. This section details the development of the conceptual structure used to guide the development of the contextual instruments in PISA 2006. By way of introduction the theoretical background to earlier international comparative education studies is sketched. For more comprehensive detail on these earlier studies and models, the reader is referred to the references at the end of this section.
17. PISA is by no means an isolated effort. Its theoretical underpinning, its instrumentation and its operational design draw on the knowledge base accumulated over the past 45 years through other international assessments, most of which were conducted by the International Association for the Evaluation of Educational Achievement (IEA). Scientific literacy is the major domain in PISA 2006 and in the field of science education, no less than seven large scale comparative studies should be mentioned where Science was either the object of the study or one of the domains assessed:

- The First International Science Study (FISS), conducted in 1970-1 in 19 countries as part of the IEA Six-Subjects Study (Comber & Keeves, 1973);
- The Second International Science Study (SISS), conducted by the IEA in 1982-3, involving 23 countries (Keeves (1992a and b), Postlethwaite & Wiley (1992), and Rosier & Keeves (1991));
- The First International Assessment of Educational Progress (IAEP I), conducted by ETS in 1988, involving 6 countries (Lapointe et al., 1989);
- The Second International Assessment of Educational Progress (IAEP II), conducted by ETS in 1991, involving 20 countries (Lazar, 1992);
- The Third International Mathematics Science Study (TIMSS), conducted by the IEA in 1995, involving 46 countries (Beaton et al., 1996);
- The TIMSS-Repeat Study (TIMSS-R), conducted by the IEA in 1999, involving 40 countries (Martin et al., 2000).
- TIMSS-Trends (TIMSS-R), conducted by the IEA in 2003, involving 46 countries (Martin et al., 2004).1

18. As in PISA, leading scholars from all parts of the world were involved in each of these investigations, through countless working papers and lengthy discussions. They collectively contributed to shaping the domain of comparative education, making this field one of the most rich and dynamic of the Sciences of Education over the last few decades. This section summarises some of the key ideas that influenced the planning of these previous investigations, with a focus on some of the models that have been employed in the IEA cross-national studies: (a) the curriculum implementation model used in most IEA studies, (b) the time and school learning model developed by Carroll (1963), (c) the causal model of school learning used in SISS, and (d) the learning opportunities model used in TIMSS. Each of these models is described briefly in the section that follows.

Curriculum implementation theory

19. From the Granna Workshop conducted by IEA in Sweden in 1971, which examined in detail the seminal work ‘The Handbook of Formative and Summative Evaluation of Student Learning’ by Bloom, Hastings and Madaus (1971), came the model (see Figure 1) of curriculum implementation that has been tested, in part, in reporting the results of the First and Second IEA Science Studies and the Second IEA Mathematics Study (Keeves, 1974; Keeves, 1992a; Postlethwaite and Wiley, 1992; Robitaille and Garden, 1989; and Rosier and Keeves, 1991).

20. The curriculum can be considered to exist at three levels: (a) the intended curriculum, (b) the implemented curriculum, and (c) the achieved curriculum, which are influenced by the antecedent and contextual factors operating at the systemic, classroom and student levels respectively. The intended curriculum is usually specified by political bodies and authorities in charge of an education system. However, in some systems the responsibility to specify what is taught resides with the board of an individual school, or with each

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1 Indeed, TIMSS 2007 commences data collection activities in October 2007 with 68 participants with results due in December 2008 (see http://www.timss.com).
individual teacher within a school. The implemented curriculum is the second level in the curriculum sequence. It is the task of each individual teacher to interpret the intended curriculum by translating it into a set of specific learning experiences that are considered appropriate for the particular group of students in a class. The achieved curriculum is the third stage. It refers to the extent that individual students have learnt from the experiences that were planned and organised for them. Figure 1 shows that the intended curriculum is set in the context of the education system; the implemented curriculum is located in the context of the school or classroom; and the achieved curriculum relates to the individual student.

Figure 1: The context and components of the school curriculum

![Diagram of the context and components of the school curriculum]

21. It is clear that the implemented curriculum is dependent on the intended curriculum, and the achieved curriculum upon the curriculum that is implemented in the classroom. A further refinement of this model might include separation of the implemented curriculum into (a) textbook and materials, and (b) opportunity to learn the items included in a test which is administered.

Carroll's Model of School Learning

22. The model of school learning advanced by Carroll (1963) has been the source of many theoretical discussions of the factors influencing educational achievement. The IEA studies provided opportunities for the investigation of this theory and for the derived models to be tested empirically (Carroll, 1975). Carroll developed this model in order to investigate the prediction of success on complex learning tasks. Three variables were specified in terms of time: (a) **aptitude** that involved the amount of time a student would require to learn a task to a specified criterion, given motivation, opportunity to learn and optimal quality of instruction; (b) **perseverance** that involved the amount of time which a student is willing to engage in active learning; (c) **opportunity to learn** that involved the amount of time provided for learning in a specific programme. In addition there were two variables that were not specified in terms of time; (d) **ability to understand instruction** that was seen as the student's preparedness to understand the specific material to be learned; and (e) **quality of instruction** that involved the structuring of the learning task, the effectiveness of presentation and the skills of the instructor. These two additional variables interacted with each other and with the three variables directly involving time. Bloom (1976) drew attention to the relevance of IEA findings on time for the study of school learning and gradually the significance of time as a key concept in learning has come to be accepted.
A Causal Model of School Learning

23. In the planning of the Second IEA Science Study a causal model derived from Carroll’s model of school learning was advanced in 1981 which was subsequently tested in the analyses of the data collected in that study at the 10-year-old, 14-year-old and terminal secondary school levels (Keeves 1992a). This causal model has also been examined in detail in several doctoral theses. The model of performance in science is shown in Figure 2 and its dependence on Carroll’s ideas is immediately evident.

Figure 2: A model of student performance

Learning opportunities model

24. The conceptual model for the IEA TIMSS study (Figure 3) was derived from the Survey of Mathematics and Science Opportunities (SMSO) in 1991 (Schmidt et al., 1996). In many respects this model parallels other conceptual models: It distinguishes between system, school, classroom and student level and also between antecedents or inputs (what students are expected to learn), processes (how instruction is organised) and outcomes (what students have learned).

25. But the main focus of the model is on the distinction between intended curriculum (located at the system level), implemented curriculum (at the classroom level) and attained curriculum (student level). In addition, it emphasises the role of teachers by conceptualising teacher education at the system level, professional development/organisation at the school level and teacher characteristics/behaviour at the classroom level. The model is primarily concerned with the explanation of opportunity to learn as a basis for student learning.
A CONCEPTUAL FRAMEWORK FOR PISA 2006

26. Both the overview presented above, and other more comprehensive reviews of educational models (see for example Scheerens & Bosker, 1997) reveal the complexity of variables and relationships that potentially influence student outcomes. The field is at the crossroads between a number of sociological, psychological, and cognitive theories, which all contribute important components to the overall picture.

27. Developing a new single, encompassing educational model for PISA would add little value to the many models already available in the literature. Rather than imposing unnecessary theoretical constraints on the thematic analyses that will be conducted using the study database, the primary role of the PISA conceptual framework for questionnaire development was to map the many components of existing models, to ensure that none of the essential dimensions are omitted from the data collection. These components were then checked against the general framework used for the OECD education indicators (INES) and the PGB priorities for PISA 2006.

28. This mapping also facilitated discussions around the feasibility and appropriateness of implementation within the constraints of the PISA design. In particular, the following aspects were considered, both in terms of restrictions and of potentialities related to the study design:

- PISA is measuring ‘knowledge and skills’ for life and does not have a strong ‘curricular’ focus. This limits the extent to which the study is able to explore relationships between differences in achievement and differences in the implemented curricula. On the other hand, consideration was given to the out-of-school factors with a potential of enhancing cognitive and affective learning outcomes.

- PISA students are randomly sampled within schools, not from intact classrooms or courses and therefore come from different learning environments with different teachers and, possibly, different levels of instruction. Consequently, classroom-level information could only be collected either at the individual student level or at the school level.

- PISA uses an age-based definition of the target population. This is particularly appropriate for a yield-oriented study, and provides a basis for in-depth exploration of important policy issues, such as the effects of a number of structural characteristics of educational systems (e.g. the use of ‘comprehensive’ vs. ‘tracked’ study programmes, or the use of grade repetition). On the other hand, the inclusion in the study of an increasing number of non-OECD countries (where the enrolment rate for the 15-year-olds age
group is maybe less than 100%) requires that retention be taken into account in the analysis of between-countries differences.

- The cross-sectional design in PISA does not allow any direct analysis of school effects over time. However, the cyclic nature of the study will permit not only the investigation of change in the criterion measures, but also in the effects of rates of change in the predictor variables.

29. As shown in the section above, many conceptual models to explain learning outcomes distinguish four levels that relate both to the entities from which data might be collected and to the multi-level structure of national education systems (see for example Scheerens 1990). These four levels are:

- the education system as a whole (setting the context for teaching and learning);
- the educational institutions (schools but also other providers of education);
- the instructional setting and the learning environment within the institutions (classrooms, courses); and
- the individual participants in learning activities (students).

30. A second dimension commonly found in many conceptual models groups the indicators at each of the above levels further:

- **Antecedents** are those factors that affect policies and the way instruction is organised, delivered and received. It should be noted that they are usually specific for a given level of the education system and that antecedents at a lower level of the system may well be policy levers at a higher level (e.g. for teachers and students in a school, teacher qualifications are a given constraint while, at the level of the education system professional development of teachers is a key policy lever).

- **Processes** group information on the policy levers or circumstances that shape the outputs and outcomes at each level.

- Indicators on observed outcomes of education systems, as well as indicators related to the impact of knowledge and skills for individuals, societies and economies, are grouped under **outcomes**.

31. The four levels and the three aspects can be represented as a two-dimensional grid with 12 potential variable types (Figure 1). This basic conceptualisation has been adapted from the conceptual framework for the Second IEA Study of Mathematics (see Travers & Westbury, 1989; Travers, Garden & Rosier, 1989) and also provided a conceptual basis for the planning of context questionnaires for the first two PISA surveys. As noted earlier, data on the instructional settings can only be collected at the individual or institutional level. However, conceptually they are still related to the level of the instructional settings (classroom, courses).
Figure 4: Conceptual Grid of Variable Types

<table>
<thead>
<tr>
<th>Antecedents</th>
<th>Processes</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level of the educational system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro-economic, social, cultural and political context</td>
<td>Policies and organisation of education</td>
<td>Outcomes at the system level</td>
</tr>
<tr>
<td><strong>Level of educational institutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of educational institutions</td>
<td>Institutional policies and practice</td>
<td>Outcomes at the institutional level</td>
</tr>
<tr>
<td><strong>Level of instructional units</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of instructional units</td>
<td>Learning environment</td>
<td>Outcomes at the level of instructional units</td>
</tr>
<tr>
<td><strong>Level of individual learners</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student background and characteristics</td>
<td>Learning at the individual level</td>
<td>Individual learning outcomes</td>
</tr>
</tbody>
</table>

32. Figure 4 shows the basic components of this two-dimensional grid. It consists of four levels and variables at each level are classified as antecedents, processes or outcomes:

- At the system-level the macro-economic, social, cultural and political context sets constraints for the educational policies in a country. Outcomes at the system-level are not only aggregated learning outcomes but also equity-related outcomes.
- At the level of the educational institution (this includes out-of-school providers), characteristics of the educational provider and its community context are antecedents for the policies and practices at the institutional level as well as the school climate for learning. Outcomes at this level are aggregates of individual learning outcomes and also differences in learning outcomes between sub-groups of students.
- At the level of the instructional units, characteristics of teachers and the classrooms/courses are antecedents for the instructional settings and the learning environment; learning outcomes are aggregated individual outcomes.
- At the student level student characteristics (like gender, age, grade) and background (like social status, parental involvement, language spoken at home, peer effects) are antecedents for the individual learning process (like perseverance, time on task) and learning outcomes (both cognitive and affective).
33. It should be noted that learning outcome variables consist not only of cognitive achievement but also of other potential learning outcomes. These include self-related cognitions (self-concept, self-efficacy), learning strategies, long-term interest in a subject or domain, educational expectations, aspirations as well as social outcomes like well-being and life skills.

34. While this mapping is useful for planning the coverage of the PISA questionnaires it is also important to supplement it with recognition of the dynamic elements of the educational system. System-level variables are important when interpreting relationships between variables at the lower levels and contradictory findings across countries are often due to differences in the structure of the educational systems.

35. From the existing conceptual frameworks and subsequent research one can derive hypotheses about (at least some of) the relationships between the elements in this two-dimensional grid. Typically, existing conceptual models assume antecedents to influence processes, which in turn produce learning outcomes, and conditions on higher levels are usually supposed to impact on those at lower levels (as for example Scheerens, 1990).

36. Some models (see Walberg 1984 and 1986; Creemers 1994) also suggest that outcome variables have an effect on the learning process and, thus, allow for a non-recursive relationship between learning process and learning outcomes. Positive or negative experiences with subject-matter learning can influence process variables such as habits and attitudes towards the learning of a subject, increase or decrease the amount of time spent on homework, etc. Another example is long-term interest in a subject or domain, which can be the outcome of learning but also affects the students' commitment to learning.

37. It also needs to be recognised that vertical or horizontal relationships might not be the only explanations for differences in learning outcomes. Antecedents at the school level, for example, are often influenced by process variables at the system level like educational policies. Another example is the possibility that the socio-cultural context (antecedent at the system level) might have an influence on instructional practices (process at the classroom level), which in turn leads to differences in student outcomes.

38. An important corollary of the intricate relationships between the various cells in Figure 4 is that each one of the observed variables is likely to convey multiple information (i.e. both information on the dimension that the variable is intended to measure, and information on related antecedents or process variables). For example, the variables identifying the study programme or grade of the students not only contain direct information on their instructional setting and curriculum, but (in many cases) also indirect information on students' probable prior level of achievement, maybe of their home background, and possibly some of the characteristics of their teachers.

39. In view of the complexity of potential relationships between these variable types, the Consortium prefers not to add any explicit causal relationships to this conceptual mapping. There are too many potential relationships between these components (including cross-level relationships) that might be relevant for PISA and which could not be integrated into one ‘general’ conceptual model.

40. Therefore, this conceptual mapping is proposed as a point of reference in the conceptual framework for PISA 2006 rather than as a general ‘PISA model’. More detailed models should be developed for particular research areas and for specific relationships. Relevant variables in these more specific models, however, could still be located within this conceptual two-dimensional matrix.

41. This conceptual mapping can be translated into a two-dimensional matrix (see Figure 5), which, for each cell, shows examples of variables that could be included in PISA.
<table>
<thead>
<tr>
<th>The education system as a whole</th>
<th>Antecedents</th>
<th>Processes</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell 1: Macro-economic and demographic context For example:</td>
<td></td>
<td></td>
<td>Cell 9: Outcomes at the level of the education system For example:</td>
</tr>
<tr>
<td>− Gross Domestic Product</td>
<td></td>
<td></td>
<td>− System level aggregates of:</td>
</tr>
<tr>
<td>− Distribution of wealth</td>
<td></td>
<td></td>
<td>Reading, mathematics and science literacy, Habits in relation to</td>
</tr>
<tr>
<td>− Cultural homogeneity</td>
<td></td>
<td></td>
<td>content domains, attitudinal outcomes, Life skills and Learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strategies</td>
</tr>
<tr>
<td>Educational institutions</td>
<td></td>
<td></td>
<td>− Equity related outcomes</td>
</tr>
<tr>
<td>Cell 2: Characteristics of educational institutions For example:</td>
<td></td>
<td></td>
<td>Cell 10: Learning outcomes at the institutional level For example:</td>
</tr>
<tr>
<td>− The wealth, values and involvement of parents.</td>
<td></td>
<td></td>
<td>− Institution level aggregates of:</td>
</tr>
<tr>
<td>− Community context</td>
<td></td>
<td></td>
<td>Reading, mathematics and science</td>
</tr>
<tr>
<td>− Source of funding, location and size</td>
<td></td>
<td></td>
<td>literacy, Habits in relation to</td>
</tr>
<tr>
<td>− Type of educational provider (e.g. out-of-school, educational media programme)</td>
<td></td>
<td></td>
<td>content domains, Affective outcomes (e.g. attitudes to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mathematics), Life skills and Learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strategies</td>
</tr>
<tr>
<td>− Differences in outcomes for students of various backgrounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instructional settings</td>
<td></td>
<td></td>
<td>Cell 11: Learning outcomes at the level of instructional setting For example:</td>
</tr>
<tr>
<td>Cell 3: Characteristics of instructional settings For example:</td>
<td></td>
<td></td>
<td>− Classroom motivation to learn</td>
</tr>
<tr>
<td>− Teacher characteristics including qualification, age, experience, commitment, subject matter orientation</td>
<td></td>
<td></td>
<td>− Use of instructional resources</td>
</tr>
<tr>
<td>− Student class or course characteristics</td>
<td></td>
<td></td>
<td>− Average classroom performance</td>
</tr>
<tr>
<td>Individual participants in education and learning</td>
<td></td>
<td></td>
<td>Cell 12: Individual outcomes For example:</td>
</tr>
<tr>
<td>Cell 4: Individual background For example:</td>
<td></td>
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<td>− Science, mathematics and reading literacy</td>
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<td>− Socio-economic status</td>
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<td>− Habits in relation to content</td>
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<td>− Parental educational level</td>
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<td>− Educational resources at home</td>
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<td>− Affective outcomes (e.g. attitudes</td>
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<td>− Ethnicity and language</td>
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<td>− Parental involvement</td>
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<td>− Age and Gender</td>
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<td>− Confidence in science</td>
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REFERENCES


42. Students’ engagement in science is an important component of scientific literacy. Engagement is crucial for the acquisition of proficiency, but it is also an important outcome of education. The relationship between engagement and achievement is almost certainly a reciprocal one: The more engaged students are in the process of learning, the more they will tend to learn, but levels of proficiency may also influence the level of engagement. Engagement of students may also be regarded as an aspect of general well-being: Students who are engaged with their learning will tend to have less stress, and fewer social and psychological problems (Boekaerts, 1993).

43. Engagement is a precondition for sustainable, continuing interest and motivation in science. It lays the affective basis for life-long learning in science, and determines students’ course choices, educational careers in secondary and tertiary education, and science-related occupational aspirations. Furthermore, engagement with science influences students’ preferences for using science in dealing with local and global problems, and developing science-based responsibility towards the self, societal issues, and environmental concerns.

44. Engagement in a subject comprises a variety of subject-related processes that are often closely related to each other (see Guthrie and Wigfield, 1997). These processes refer not only to students’ active involvement in learning, but also to students’ appraisals of their own ability to succeed in a subject, their emotional relationships with this subject, their motivation to learn, etc. All of these processes can refer to different contents defined by the different sciences, and to different contexts defined by life domains to which the sciences can be applied. Processes of engagement can differ between these contents and contexts. For example, a student may be interested in health-related issues, but disinterested in electronic technology.

45. Relevant processes of engagement include students’ own ability appraisals in science, their beliefs about the value of science, their emotions, interest, and motivation to learn, as well as their choices of learning strategies and science-related behavioural activities in and out of school. Within the context of this research area, therefore, the following basic questions will be addressed regarding students' engagement with science:

- **Self-related cognitions**: Do students believe they can succeed in science?
- **Value Beliefs**: Do students value scientific inquiry?
- **Emotional factors**: How do students feel about learning science?
- **Motivational orientations**: Are students interested in science?
- **Behaviour-related variables**: How do students learn science?

46. In the PISA 2006 scientific literacy framework, relevant life situations that involve science and technology are defined for assessment purposes. These are termed ‘contexts’ and a context is considered to be an area of application of scientific knowledge – including health, resources, environment, hazards, and frontiers – within a range of settings: personal, social, and global. The scientific literacy framework provides a detailed discussion of contexts of scientific literacy such that there is no need for further elaborating them here (see PISA 2006 Scientific Literacy Framework).

47. Much previous research on students’ engagement with science has used the concept of ‘attitude’ to label variables of engagement. Generally, attitudes are an individual’s cognitive, affective, and behavioural reactions to some object or phenomenon. In research
on students’ science learning, however, researchers have ascribed different meanings to
the term ‘attitude’. For example, the distinction between attitude toward science and
scientific attitudes (such as open-mindedness and respect for logical arguments) has not
always been clarified (Simpson et al., 1994). Furthermore, multiple dimensions such as
attitude toward the use of science, attitude about scientists, perceived value of science,
confidence in one’s own capabilities in science, or enjoyment and interest in science have
often been subsumed under the general label of ‘attitude’, instead of differentiating them.
Not surprisingly, many research studies from the past several decades have found either
no or only small correlations between ‘attitude’ toward science and achievement (Rennie
and Punch, 1991; Simpson, et al., 1994), in contrast to research on specific dimensions of
students’ engagement.

48. Within the conceptual framework for PISA 2006 contextual information, components of
engagement can be regarded as processes determining the acquisition of proficiency and
as outcomes of learning at the individual level. Similarly, at the levels of instructional
units and educational institutions, students’ engagement in science is part of the learning
environment of classrooms and schools, and part of the educational outcomes at these
levels. At the level of educational systems, students’ engagement with science is an
important outcome affecting the scientific and technological productivity, and science-
based responsible action, of nations (see paragraph 32, previous chapter).

49. Students’ engagement in science is also incorporated into the scientific literacy framework
of PISA 2006. In that framework, processes of engagement in terms of self-related
cognitions, values, emotional and motivational orientations, and actions are regarded as
important components of students’ affective responses to science, and therefore as
components of scientific literacy. In addition to students’ engagement, responsible
attitudes towards resources and the environment are also regarded as part of students’
affective response to science (e.g., OECD, 2006, pp. 21-25).

Self-related cognitions

50. *Self-related cognitions* are supposed to have a considerable impact on goal setting,
strategy use and achievement (Zimmermann, 1999). Science-related self-appraisals tend to
be gender-linked and may partially explain gender differences in motivation and
achievement in science (Reiss and Park, 2001). Generally, self-related belief systems can
be grouped into types: beliefs of self-efficacy, control beliefs, and self-concepts.

51. *Self-efficacy* - that is, student’s ‘judgements of their capabilities to organise and execute
courses of action required to attain designated types of performances’ (Bandura, 1986, p.
391) - is deemed to have a strong influence on individual choices, efforts, perseverance,
and emotions related to the tasks. Self-efficacy can be regarded as one part of a
comprehensive personal theory about the learner’s own learning process, which directs his
or her own learning (Bandura, 1993). Bandura (1986) stated that self-efficacy plays an
important role in determining behaviour - that is, feelings of confidence about a specific
problem are crucial to an individual’s capacity to solve that problem. Research has
generally confirmed a relationship between self-efficacy and student performance, though
different sizes of correlation were reported, often depending on the types of self-efficacy
measures that were used (Multon, Brown and Lent, 1991).

52. Research on *control beliefs* also focuses on expectations by students of their ability to
distinguished between strategy beliefs, i.e. expectations about what is necessary to be
successful, capacity beliefs, i.e. expectations about one’s own general ability to succeed
(self-efficacy), and control beliefs, i.e. expectations about whether or not one is able to
succeed, without reference to any specific means or capacities. Maximisation of all three
processes is seen as relevant for producing optimal levels of engagement in learning (see
Positive self-concept can be seen as a desirable outcome variable of education (Branden, 1994), and its enhancement is one of the goals of policy-makers in many countries. Marsh and Shavelson (1985) argued that self-concept is a multi-dimensional construct and distinctions between verbal, mathematical and (general) academic self-concept are required. Marsh, Byrne and Shavelson (1988) assumed that students evaluate their own performance through social comparison processes; that is, their evaluation is based on their position relative to other students and their relative performance on different school subjects. Furthermore, it has been observed that school average of achievement tends to have a negative effect on self-concept; that is, students with same proficiency levels often have different levels of self-concept depending on the overall performance of a school (Marsh, 1990).

Value beliefs

Value beliefs about science pertain to students’ general appreciation of science and scientific inquiry, and to perceptions of the personal, subjective importance of science. Value beliefs can be regarded as an important part of students’ attitudes towards science. Students’ general appreciation of science and scientific inquiry is closely related to their epistemological beliefs about science (Fleener, 1996; Hofer and Pintrich, 2002). General appreciation has to be differentiated from the personal value of science. In expectancy-value theories of human agency, personal values are assumed to be essential antecedents of individual motivation, emotion, and behavioural decision-making (Heckhausen, 1991; Pekrun, 2000). Personal values can be regarded as antecedents of students’ emotional feelings about science, their motivation to learn for science, and their motivation for long-term engagement in science and related educational and occupational career choices.

Students’ general appreciation of science implies appraisals of science as important, independent to its personal value for the students’ own career. Facets of appreciation pertain to valuing the contribution of science and technology for understanding the natural and constructed world, and for the improvement of natural, technological, and social conditions of life. Appreciation also pertains to valuing the contributions to science and technology made by men and women from many societies and cultural backgrounds (Carstensen, Rost and Prenzel, 2003).

General appreciation of scientific inquiry implies to value scientific ways of gathering evidence, rational reasoning, and communicating conclusions when trying to understand the world and solve problems. Facets of this construct include valuing the importance of considering alternative perspectives, ideas and explanations, valuing the use of factual information and rational explanations when analysing and evaluating, valuing social interactions for building rational, evidence-based conclusions, and valuing logical and careful processes for drawing conclusions (see OECD, 2006).

Personal value of science and science-based reasoning has to be differentiated from a person’s general appreciation of science. People may be convinced that science is generally important, but not so for their own lives and behaviour. Similar to motivation in general, personal values may be of ‘intrinsic’ or ‘extrinsic’ types. Extrinsic values of science imply to value science and the scientific advancement of understanding the world for its own sake, whereas intrinsic values pertain to the instrumental, individual usefulness of science and scientific inquiry. Students who ascribe personal relevance to science are more likely to characterise their learning as integrated with their identities (Thompson and Windschitl, 2002).

Important extrinsic values include (a) the value of scientific knowledge and inquiry for the students’ current and future everyday life (e.g. for solving technical, psychological, and health-related problems); (b) the value of science for attaining current and future educational goals; and (c) the value of science for future occupational career choices. General vs. personal, and intrinsic vs. extrinsic values do not contradict each other. Rather, it can be assumed that appreciating the general value of science positively affects
the perceived future-oriented personal importance of this domain, continuing interest in the domain, and career decisions in favour of science-related occupations.

**Emotional factors**

59. Emotional factors play a critical role for learning and teaching, because students enjoying learning may develop interest in science and continuing motivation to learn, whereas negative emotions like anxiety and boredom may lead a student to avoid the subject when possible. Generally, students’ emotions are fundamental for their interest and motivation, facilitate the use of different learning strategies, and influence the willingness to self-regulate learning and performance instead of relying on external guidance (Pekrun, Goetz, Titz & Perry, 2002a). Emotional attitudes lay the basis for long-term learning and science-related career decisions.

60. United States national assessment data, however, provide evidence that, whereas primary students still tend to enjoy science, emotional attitudes toward this subject change dramatically among students in secondary education (Harms, Bybee & Yager, 1979; Neathery, 1997). Similar trends have been observed in international studies (see, for example, Keeves & Morgenstern, 1992).

61. Most research on emotional factors has focussed on achievement-related anxiety, test anxiety being the most prominent construct (for overviews, see Hembree, 1988; Zeidner, 1998). This research has shown that test anxiety undermines interest and intrinsic motivation in a subject. Test anxious students tend to avoid achievement situations, although anxiety can also lead to increased investment of effort aimed at failure avoidance in individual cases. In situations not allowing manifest avoidance, behavioural withdrawal is replaced by cognitive distraction and task-irrelevant thinking, which leads to impaired learning and achievement in cognitive domains. Consequently, test anxiety correlates negatively with students’ academic achievement. Average test anxiety values are significantly higher in girls than in boys in student populations of many countries.

62. Studies on science anxiety parallel research on test anxiety. As with test anxiety, science anxiety is often gender-related and usually found to be negatively associated with achievement (Anderson & Clawson, 1992; Chiarelott & Czerniak, 1985, 1987; Mallow, 1994). Achievement-relevant negative emotions other than anxiety are students’ anger, shame, hopelessness, and boredom. Whereas anger and shame can activate or deactivate students’ motivation and effort, and thus exert ambivalent effects on achievement (Turner & Schallert, 2001), hopelessness and boredom are deemed to be universally detrimental.

63. It can be assumed that science boredom prevents the development of interest in science, reduces both intrinsic and extrinsic motivation, undermines attention by triggering irrelevant thoughts as implied by daydreaming, and makes any processing of science-related information shallow (Pekrun, Goetz, Titz & Perry, 2002a), thus negatively affecting the development of science literacy. Boredom can be experienced both by gifted high-ability students for whom demands of classroom instruction are too low, and by low-achieving students lacking the ability to deal with science curricula in subjectively meaningful ways.

64. Positive emotions towards science like enjoyment of learning science reflect the extent to which students are emotionally attached to learning and experience learning this subject as a meaningful activity (Glaser-Zikuda, Mayring & von Rheoneck, 2003). Enjoyment enables students to experience flow when dealing with science, which implies on-task focussing of cognitive resources and attention facilitating efficient learning (Nakamura, 1988). Enjoyment and flow enhance the self-regulation of learning and the use of flexible learning strategies like elaboration, organisation, and creative problem solving (Pekrun, Goetz, Titz & Perry, 2002b). Furthermore, enjoyment of science is probably essential for developing long-term, continuing interest and motivation to learn science, and to decide for science-related career options.
Motivational orientations

65. Motivating students to learn is crucial in the process of fostering their engagement. Motivational preferences can be viewed as either ‘intrinsic’ or ‘extrinsic’. Whereas intrinsic motivation relates to internal factors like individual’s interest and enjoyment of a subject, extrinsic motivation is based on external incentives for learning such as perceived instrumental importance and anticipated future rewards (see Dev, 1997). Achievement motivation can be both intrinsic (relating to success and failure per se) and extrinsic (when relating to the consequences of success and failure).

66. Interest and intrinsic motivation. An intrinsic motivational preference is subject-related interest, which affects continuity and intensity of involvement with learning, independently of the general motivation to learn (see an overview on interest research in Baumert and Koeller, 1998). Interest is closely related to the enjoyment of science, and to the perceived personal value of science (see Schiefele, 1991). Interest and intrinsic motivation are viewed as having positive effects on time on task, more comprehensive learning strategies, as well as performance and activity choices in the absence of extrinsic rewards (Lepper, 1988).

67. Achievement motivation. Recent research on students’ motivation has conceptualised motivation in terms of students’ achievement goals (e.g. Ames, 1992; Elliot & McGregor, 2001; Pintrich, 2000). Mastery goals are based on criterion-related reference norms defining attainment in terms of standards of competence, or to intra-individual norms of competence gains over time, whereas performance goals relate to social comparison norms. For both mastery and performance, approach and avoidance goals can be distinguished (e.g. performance approach goals relate to being better than others; performance avoid goals relate to the avoidance of low achievement, as compared to others). Similar to interest and intrinsic motivation, mastery approach motivation has been shown to foster comprehensive learning, continuing motivation, and achievement. Performance avoidance motivation can lead to withdrawal, lowered effort, and reduced performance (Midgley, 2002).

68. Instrumental, future-oriented, and continuing motivation. In longitudinal studies, instrumental motivation has been found to be an important predictor for course selection, career choice and performance (Eccles, 1994; Eccles & Wigfield, 1995; Wigfield, Eccles & Rodriguez, 1998). Future-oriented dimensions of instrumental motivation are assumed to be of specific relevance for long-term, continuing engagement with a subject (Husman & Lens, 1999; Lens, Simons & Dewitte, 2001). The motivation for life-long investment of effort and time in science is enhanced by stable individual interest in the sciences, and by instrumental considerations based on the importance of science for the attainment of career and life goals.

69. Educational and occupational aspirations. Students’ educational and occupational aspirations relating to science can also be assumed to shape their motivation to learn, their readiness for long-term engagement with science, and their decisions for tertiary education and occupational careers relating to science.

70. Intrinsic, achievement, instrumental, and future-oriented motivational preferences determine how much time and energy students invest in learning, as well as their choice of courses and learning strategies (see Deci & Ryan, 1985; Tamir 1991). Though all kinds of motivation can have positive effects on learning outcomes, there is evidence that students who are more intrinsically motivated than extrinsically, and more mastery approach than performance avoidance oriented, perform better (Brooks et al., 1998; Lumsden, 1994) and have a more stable motivational basis for life-long learning.

Behaviour-related variables

71. Students may develop different types of learning strategies that shape their learning behaviour. Macro-strategies like self-regulation of learning, inquiry-based learning, or
choices of cooperative vs. competitive settings of learning, can be distinguished from micro-strategies pertaining to specific cognitive, meta-cognitive, and volitional techniques of regulating one’s learning.

72. **Self-regulation vs. external regulation of learning.** Self-regulation of learning implies setting one’s own goals for learning, to plan sequences of learning and select appropriate cognitive and volitional strategies, and to self-monitor one’s learning and evaluate its outcomes (Zimmerman & Schunk, 2001). In contrast, external regulation implies to rely on external guidance, and to let teachers set goals, prescribe strategies, and evaluate outcomes. Educators and policy-makers regard competences and motivation to self-regulate learning as important educational outcomes, since self-regulation is a precondition for life-long voluntary learning and engagement with science.

73. **Contexts that promote inquiry-based learning.** In science learning, classroom practices and cognitive learning strategies can vary tremendously in terms of the degree of scientific inquiry that the students experience. In classrooms with a high degree of student participation in scientific inquiry, students will learn by asking testable questions, designing experiments, collecting and analysing data, and communicating the results of their work. Research indicates that student achievement improves when they are engaged in science learning through inquiry (Anderson, 2002; Haury, 1993; Shymansky et al., 1990).

74. **Cooperative vs. competitive learning.** Learning behaviour is also influenced by the students’ preference for learning situations. Preference for cooperative learning in groups (Marsh, 1999) and preference for competitive learning, for example striving to be better than others (Owens and Barnes, 1992), are two salient aspects. Cognitive and non-cognitive benefits of cooperative goal structures have been investigated in the past. In a meta-analysis of studies, Slavin (1983) showed that cooperative learning methods per se do not affect achievement. However, cooperative learning including both individual accountability and group rewards/goals was reported to have positive effects. In PISA 2000, students that preferred cooperative or competitive learning methods tended to perform better than other students (OECD, 2001, p.p. 114-115).

75. **Cognitive and meta-cognitive strategies.** The main cognitive strategies are rehearsal or memorisation (learning key terms, repeated learning of material etc.) and elaboration (making connections to related areas, or thinking about alternative solutions). Control strategies are meta-cognitive strategies that involve planning, monitoring, regulation, and evaluation of learning (see Weinstein, Husman and Dierking, 2000).

76. **Volitional strategies.** Volitional processes also may have an impact on learning behaviour, i.e. students will have different levels of action control in addition to the motivational factors influencing their actual behaviour. One example of a volitional factor is the level of effort and perseverance students invest in their learning. Effort and perseverance are difficult to distinguish and are therefore often regarded as two aspects of the same latent factor. Within the conceptions of self-regulated learning, this factor is regarded as one important component behaviour (O’Neil & Herl, 1998). Schunk (1990) suggests that the persistence of students on difficult tasks is due to the belief that effort enhances their ability, i.e. their ‘strategy beliefs’ about what can be achieved through which means (see also Skinner, Wellborn & Connell, 1990).

77. **Time spent on learning.** Active involvement in the learning process has different connotations: Clearly, the time spent on learning is one crucial factor. Research has shown that time allocation (i.e. quantity of schooling) itself does not show a strong relationship with achievement (Blai, 1986; Fisher & Berliner, 1985; Karweit 1976). However, there is evidence that there is a moderate positive association between measures of specific ‘time-on-task’ (e.g. learning time spent on a subject) and student achievement from a number of studies (e.g. Guida, Ludlow & Wilson, 1985), including the National Education Longitudinal Study (NELS) 1988 (Singh, Granville & Dika, 2002).
78. **Course choices, non-compulsory activities, and out-of-school activities.** Learning time is not the only component of active student involvement in the learning process. Student participation in non-compulsory activities related to science or choice of course combinations with an emphasis on this subject are also important indicators of engagement. Furthermore, out-of-school activities relating to science can contribute considerably to students’ engagement and learning in science. As in school-based learning, such activities can imply different types of actions (like reading books or magazines, going to museums, observing natural phenomena, or performing science experiments), and can relate to different contents and contexts of the sciences.

**Implications: Relations and profiles of components of engagement**

79. The components of engagement in science that have been discussed are related to each other. It is often a theoretical question as to whether component concepts that are empirically correlated should be treated as separate or rather as integrated constructs (e.g. personal values and interest in science; or engagement pertaining to health-related, environmental, and resources issues). Previous research suggests that the relationships (a) between most of these constructs and (b) between most of these constructs with achievement are reciprocal. All of these constructs are important for students’ choice of learning strategies, time on task, and – in consequence – academic performance and long-term engagement with science. However, self-related cognitions, values, emotional factors and motivational orientations, as well as behaviour-related variables may also be affected by achievement.

80. The use of general questions on engagement within the questionnaires and contextualised engagement items embedded in the test allows the construction of complex profiles of engagement. For example, whereas one student may appreciate science both generally and on a personal level, another student may value science in general while denying its relevance for his or her own life. Students may also show different profiles of engagement across contexts and contents of science tasks. For example, some students may enjoy learning all aspects of science, whereas others are interested in learning only specific contexts of science (e.g. learning about personal health issues like nutrition might be preferred to learning about global hazards such as climate change).

81. Engagement profiles may be linked to gender (Schibeci, 1984), student background, instructional programmes, and educational systems. They can be regarded as meta-indicators of engagement at the individual, instructional units, educational institutions, and educational systems levels.

**POTENTIAL POLICY ISSUES**

82. The following policy questions in this area could be addressed by PISA 2006:

**Self-related cognitions and value beliefs**

- Data from PISA 2006 may be used to analyse the relationship between self-related cognitions, value beliefs and performance in the area of science. To what extent are self-related cognitions and perceived values of science influenced by student characteristics, family background and experience with science learning?
- Self-related cognitions and value beliefs have often been found to contribute to choice of educational pathways and careers. This is especially important with respect to possible inequities (for example by gender): Career choices by students (e.g., whether science-related or not) may be made on grounds of self-perceptions about skills than on actual abilities (see also the Chapter on Scientific Literacy and the Labour Market).
Emotional factors and motivational orientations

- Enjoyment and intrinsic motivation tend to be lower at the secondary level and students often seem to lose interest after primary education (and to develop science anxiety or boredom instead). To what extent do educational systems vary in this respect and to what extent do these differences depend on heterogeneous versus homogeneous modes of delivery of science instruction?
- Science is clearly an important subject for many future educational and professional career options of students. To what extent do extrinsic, future-oriented motivational preferences, and educational and occupational aspirations differ depending on programme orientation, and what is the effect of motivational orientations and aspirations on achievement?

Behavioural variables

- Over the past decades efforts have been spent on reforming science education by placing more emphasis on inquiry-based teaching and learning, solving non-routine problems, and higher order thinking. What is the relationship between the learning strategies employed and the outcomes of learning? How different are the learning outcomes when students experience science as inquiry? And are there differences between educational systems/countries and between different kinds of study programmes in countries with heterogeneous school systems?
- PISA 2000 has shown that the relationship between homework and achievement is rather complex and is influenced by characteristics of the educational system. This underlines the need for a measurement of learning time components and their relationship with achievement. To what extent do study programmes and/or tracks differ with respect to the learning time on science within countries? Are there differences between compulsory and voluntary learning time with respect to their relationship with science literacy?

Profiles of engagement and attitudes

- What are the profiles of students’ engagement with science? In which ways are students characterised by different profiles of processes of engagement, and by different profiles of engagement relating to the contexts of science? Do these profiles depend on gender (e.g. gender-linked interest in biological vs. technological issues), student background, educational programmes, and the organisation of educational systems?
- The relationship between engagement, attitudes and achievement is not clear-cut and can be further examined during PISA 2006. What is the relationship between students’ engagement with science and their achievement in science? Does this relationship differ by age, gender, programme orientation, family background, or out-of-school experiences?

IMPLEMENTATION

83. Many of the questions and issues that arise within this research area were dealt with through the student questionnaires in PISA 2000 and 2003. As in PISA 2003, it is expected that the more proximal to the domain of interest these kinds of measures are – that is, the more they are focused on specific science-related dimensions of engagement – the more powerful they will be as correlates of educational processes and outcomes, and the more suitable they will be for descriptive and explanatory purposes as part of an international comparison.

84. However, an important change from the approach taken in PISA 2000 and 2003 is apparent. Whereas the student questionnaire provides measures of different processes of engagement in general, some specific measures of science engagement in different contexts are included in the science test.
85. The tasks in the science test can be used for assessing key engagement processes throughout a range of contexts without needing too much additional testing time. Nevertheless, limits of testing time and students’ test motivation imply that it is not possible to get measures of all relevant processes of engagement for all relevant contexts of science in PISA 2006. As proposed by the scientific literacy framework, engagement processes to be assessed within task contexts are perceived value of science (specifically, ‘support for scientific enquiry’) and interest in science (specifically, interest in learning about science).

86. A third key affective area prioritised in the scientific literacy framework is responsible attitudes toward resources and the environment. This will be assessed through an item battery in the student questionnaire.

87. The innovative format of the PISA 2006 assessment of engagement will make it possible to analyse profiles of engagement processes as assessed by questionnaire scales, as well as profiles of engagement with different contents and contexts as assessed by items embedded in the science test. For example, this format will allow analysis of the homogeneity of student interest in science across different task contents, and the dependency of profiles and homogeneity upon gender, background, and educational programmes (like integrated science education vs. science instruction as part of different school subjects).

88. Another change from PISA 2003 is the inclusion of a parent questionnaire as an international option. Measures of parents’ perceptions of students’ engagement with science, including their aspirations and out-of-school activities relating to science, are included in the parent questionnaire. Also included in the parent questionnaire are parallel questions on the parent’s general and personal values of science – which can be examined alongside the student’s general and personal values of science for evidence of intergenerational transmission of values and influences on scientific literacy.

Engagement constructs in the PISA 2006 questionnaires

89. Following extended discussions with the Questionnaire Expert Group, consultations with the Science Expert Group and National Project Managers, and review of the empirical outcomes of pilot and Field Trial data, the following engagement constructs were recommended to the PISA Governing Board for inclusion in the PISA 2006 Main Survey.

90. The following constructs were measured with item batteries included in the student questionnaire:

Self-related cognitions
- **Science self-efficacy** comprise items covering three themes: identification of science questions; scientific explanation of phenomena; and use of scientific evidence.
- **Academic self-concept in science**

Value beliefs
- **General value of science**
- **Personal value of science**

Emotional factors
- **Science enjoyment**
- **Interest in learning science**

Motivational orientations
- **Future-oriented motivation (general instrumental)**
- **Future-oriented motivation (science career specific)**
- **Aspirations including educational and occupational aspirations**

Behaviour-related variables
- **Learning time**
- **Out-of-school science activities**
- **Science course taking**
  In addition four constructs related to scientific inquiry in the classroom were included. These later constructs are elaborated further in the section on teaching and learning:
  - **Student interaction in science classes**
  - **Hands-on activities in science classes**
  - **Designing and applying scientific investigations in science classes**
  - **Science taught as applications.**

91. An item battery was included in the school questionnaire to measure:
  - **School-based activities promoting interest in science**

92. In addition the following constructs were measured in the international option² of a parent questionnaire:
  - **Parents' the general value of science**
  - **Parents' personal value of science**
  - **Parents’ perceptions of student’s interest in continuing to engage in science** (study and/or career).
  - **Parents’ perceptions of the student's past out-of-school science activities**

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² Countries may choose whether to administer the parent questionnaire. It is not a core component of the PISA study.
REFERENCES


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32.
SCIENTIFIC ATTAINMENT AND THE LABOUR MARKET

Alexander W. Wiseman

ELABORATION

93. Linking school and work is a long-standing policy priority among OECD member nations because youth are a nation’s economic future (OECD, 1999). Scientific literacy among youth has been identified as one of the most effective indicators of youths’ preparation for participation in the labour market. The link between scientific literacy and the labour market occurs in three stages: schooling, training, and career (Alromi and Wiseman, 2003). These stages define benchmarks in the formation of students’ cognitive and affective dispositions towards scientific literacy and the labour market.

94. The schooling stage consists of science-related work or problem solving that takes place during schooling that is independent of training for an occupation or career employment. The training stage begins when formal schooling either overlaps with out-of-school work or when work becomes career-oriented and more important than schooling (e.g. after formal schooling ends). The career stage begins when an individual’s job becomes a career-track position and schooling or training is de-emphasised.

95. The majority of the literature that deals with schooling and its connection to the labour market, however, does not include tertiary education as a significant component. This does not mean that all of the literature is focused on non-university-bound youth, but it does mean that tertiary education is seen as a unique component in the transition process that does usually somehow involve training either directly or indirectly. There is a body of literature on tertiary education and its role in the transition from school to work (Bragg, 2001; Stern, Finkelstein, Stone, Latting, and Dornside, 1995; Zemsky, Shapiro, Iannozzi, Cappelli, and Bailey, 1998). Since there are many levels of tertiary education, the discussions are usually split into those that deal with more vocationally-oriented post-secondary education (e.g. technology training), community or junior colleges (in the United States in particular), and professions-oriented 4-year universities (Arum and Hout, 1998; Brint and Karabel, 1989; Commission on the Skills of the American Workforce, 1990; Müller, Steinmann, and Ell, 1998).

96. Notwithstanding the distinctiveness of the tertiary education literature the three phases of schooling, training, and career still apply regarding labour market discussions (Bragg, 2002; Dougherty, 1987; Mobley, 2002). At the tertiary level there is more of a mix of schooling and training, especially in professionally-oriented degree programmes (like education/teaching, medicine, law, engineering), but otherwise the phases are still in tact. The focus of the three stages is not when they occur in relation to an individual's life course as much as when they occur in relation to each other. In other words, do the schooling, training, and career stages occur distinctly or do they overlap?

97. There are at least two fundamental educational models for linking scientific literacy to the labour market based on the schooling and training stages. One is a school-oriented educational model (schooling stage only) and the other is a work-oriented educational model (schooling and overlapping training stage). These models assist in what has been called ‘sponsored’ and ‘contested’ mobility, respectively (Winfield, Campbell, Kerckhoff, Everett, and Trott, 1989).

98. The school-oriented educational model consists of schooling alone through the completion of formal school. As a result, this model relies on a combination of training and career beginning upon employment with a company. Although schooling is largely independent of industry according to this approach, employers maintain relationships with schools and consider academic grades and credentials during the hiring and recruitment processes.
The school-oriented education model is meant to serve as a foundation for future work by developing flexibility, critical thinking, and decision-making in students. Students in educational systems incorporating this model are expected to understand that their focus in school is on the mastery of complex and often abstract knowledge related to science and other subjects. Once they leave school and enter the labour market, it is understood that their employer will train them to do whatever work is necessary (Sturges and Guest, 2001). The key is that they have a strong knowledge of science, mathematics, and technology in order to be able to learn whatever job-specific skills their employers may demand.

According to the school-oriented educational model, training is a function of career; therefore, employers train generally-educated new employees in company and career specific methods. The anticipated result is that these new employees will combine their knowledge of a content area (e.g. science) with skill-specific vocational applications thus leading to high productivity and quality work. Students in the school-oriented model often understand that their labour market participation is inextricably tied to their educational attainment and achievement. Therefore, educational systems that follow the school-oriented model often produce some of the highest performing students on international math and science assessments like PISA.

The Japanese educational system provides one example of the school-oriented educational model for linking scientific literacy to the labour market. Despite its advantages, Sako (1994) asserts that even with the immediate employment security this system supplies, the transition from school-to-work may be too sudden and result in high employee attrition due to the inability to adjust to work situations.

In contrast, the work-oriented educational model is based on the widely-discussed vocation education and training approach, which is prevalent in many nations. This model promotes more vocationally-oriented scientific literacy through the overlap of the schooling and training stages. In this model employers are encouraged to become involved in the training of students throughout their secondary schooling (Hamilton and Hamilton, 1994). As a result, school leavers are well-qualified workers who often leave school with professional certification and contacts already in place (Furlong, 1993; Hamilton and Hurrelmann, 1994). Germany’s educational system is one that incorporates the work-oriented educational model. For example, Vickers (1995), when describing and interpreting the characteristics of Germany’s system, reports that German employers act as senior partners alongside career advocates (unions) and educators in the professional development and training of German youth.

Because students in systems incorporating the work-oriented model experience this sort of partnership between school and work, policymakers often assume that students have appropriate aspirations and expectations for future labour market participation (Hamilton, 1990b). These cooperative school-work efforts often result in some sort of formal educational or professional credential. Poczik (1995) suggests that a recognised credential in, for example, an area related to scientific literacy is a big help to students in terms of their own attitudes towards science-related work and employers’ attitudes toward hiring these students to do science-related work. Of course, labour market representatives must appreciate the value of a credential for it to have worth, but in work-oriented educational systems this is an understood element.

An additional bonus of the work-oriented educational model is that students receive content-related (e.g. science-related) vocational training alongside and in conjunction with content-related academic content. Proponents of this model suggest that new employees will connect their theoretical scientific literacy with the vocational application of science skills.

Although the three stages of transition from school to work are relatively constant, the way that educational systems incorporate educational models based on these stages varies from nation to nation (Raffe, Brannen, and Croxford, 2001; Roberts, 1998). As a result the
connection between scientific literacy and the labour market is a subject of frequent debate and discussion among policymakers.

**POTENTIAL POLICY ISSUES**

106. Scientific literacy and labour market policy issues that could be addressed by PISA fall into the following categories: international economic competition, employability skills, vocational vs. academic education, educational attainment and achievement, opportunity structure, and adolescents’ aspirations and expectations.

**International Economic Competition**

107. International competition and economic interdependence create a community in which all nations have a stake in scientific literacy (Ball, 1990; Carnoy, 1998; Deboer, 2000). As participation in the international community becomes increasingly important for individual nations, research-supported discussions about a standardised and consistently-skilled labour force become more frequent in the policy-relevant literature (Crowson, Wong, and Aypay, 2000; Hughes, Bailey, and Karp, 2002). Around the world there are debates at all policymaking levels on educational priorities related to academic versus economic outcomes (Ashton, Green, Sung, and James, 2002; S. Taylor, Rizvi, Lingard, and Henry, 1997), and scientific literacy is one of the key factors in these debates. Ensuring that students attain appropriate levels of scientific literacy is one of the ways that schools help students be productive contributors to a nation’s economy.

108. The link between what students think, learn, and do in school and their awareness, knowledge, and participation in the labour market is the main component of most policy-related discussions of scientific literacy and the labour market. PISA can provide data that can contribute to this policy discussion. In particular, data on students’ scientific literacy and students’ awareness knowledge and aspirations in the labour market can be described and analysed in terms of social, cultural, and ethnic indicators which shape both scientific literacy and labour market knowledge in 15-year-olds.

**Employability Skills**

109. Although not directly related to scientific literacy, employability skills are frequent fodder for educational policymakers concerned with international economic competition and the link between schooling and the labour market (Ashton et al., 2002). Employability skills form the foundation that many policymakers, employers, parents, and students believe are necessary to enter and productively contribute to the labour market following full-time compulsory schooling, although research shows that most employers do not use information related to employability skills when making hiring decisions (Miller and Rosenbaum, 1997).

110. These skills fall into three categories: personal, social, and capacity (Alromi and Wiseman, 2003). Personal skills are those that represent an individual's self-discipline, self-confidence, ambition, willingness to work, promotability, and ability to communicate and problem solve. Social skills represent the characteristics that influence individuals’ ability to work well with others and contribute to an employment team. Examples of social skills are teamwork, leadership, adaptability, and reliability. Finally, capacity skills represent individuals’ content-specific or technical knowledge. Capacity skills at the basic competency level include core subject knowledge in mathematics, science, and language as well as more technical understanding of computer technology and even typing ability. Capacity skills also represent individuals’ trainability and creativity.

111. The relationship between students’ scientific literacy and the labour market is a part of the policy debates related to the capacity side of employability skills. It is also this third arm of employability skills that fits specific content into the relationship between scientific literacy and students’ aspirations, expectations, and future labour market productivity.
Vocational vs. Academic Education

112. Research shows that the curriculum students receive in school does influence their future career choices (Te Riele and Crump, 2002). Policymakers believe that in order to link education to labour market outcomes curricula should (a) focus on improving and providing basic employability skills, (b) inform students about opportunities in the labour market that relate to the curriculum learned in school (e.g. science), and (c) provide specific information about how to apply curriculum learned in school to future work situations (Lovejoy, 1998; A. Taylor, 2002).

113. In discussions about employability skills, the temptation for policymakers is to link schooling to the labour market by focusing on vocational education that specifically trains students in certain occupational skills (Ball, 1990; Leumann and Taylor, 2003; Raffe, Brannen, Fairgrieve, and Martin, 2001; Shavit and Müller, 2000). Late 20th century labour market conditions, however, have led to a decline in technical skills-oriented vocational education around the world (Raffe, 1993). In fact, in most nations technical skills-oriented vocational education as an independent educational track is fading (Benavot, 1983). As a result, vocational education is in transition and increasingly emphasises general categories of cognitive skills and workforce preparation over occupation-specific training (Howieson, 1993).

114. The shift away from strictly vocational education has been dubbed the ‘new vocationalism’ (Benson, 1997; Grubb, 1996; Leumann and Taylor, 2003) and is partly due to the advent of what is called the ‘knowledge-based’ economy (Te Riele and Crump, 2002). To meet the needs of a knowledge-based economy there has been a shift in policy emphasis from purely technical skills-oriented vocational education to a new vocational education that blends some technical skills training with academic learning and employability or soft skills training (A. Taylor, 1998). In fact, many countries are combining vocational with general education courses and curricula in spite of differences in educational structure and governance among nations (OECD, 1994). The goal for policymakers is to help students become flexible and adaptable workers (i.e. flexible specialists) in a quickly-evolving technological labour market (Hamilton, 1990a; Sedunary, 1996).

115. Data from PISA could be used to help policymakers understand how students’ scientific literacy (1) meets both vocational (applied) and academic (theoretical) labour market needs, (2) impacts students’ attitudes, aspirations, and expectations regarding the labour market, and (3) results from school content and instruction that incorporates information about labour market opportunities.

Educational Attainment and Achievement

116. Many policymakers base their understanding of the link between schooling and the labour market on national achievement rankings from international assessments of academic achievement like PISA (Brown, 1998; LeTendre, Baker, Akiba, and Wiseman, 2001). These discussions often identify educational attainment and achievement as another contributing factor to national economic productivity, growth, or stability (Psacharopoulos and Velez, 1993). In fact, in terms of potential policy issues related to scientific literacy and the labour market, educational attainment and achievement are probably the most important because they are typically perceived as being easy to measure, report, and interpret. This is, however, a common mistake.

117. The relationship between educational attainment, achievement, and the labour market is, in fact, not as straightforward as it is often made to appear (Irandoust and Karlsson, 2002; Sicherman, 1991). Educational attainment in science is different from science achievement both in definition and in terms of the effect on adolescents’ future labour market participation and outcomes. Students who attain high levels of education have generally completed courses at an advanced level—even if they completed these courses
with barely passing grades. In contrast, students who achieve high scores on science assessments are performing at high levels even if they have only taken a basic science course. Scientific literacy corresponds more closely with achievement than attainment, since literacy requires proficiency, whereas attainment may not. Therefore, considering the impact of both science attainment and achievement on the labour market is important.

118. The impact of science attainment on the labour market has been seen primarily in terms of its screening or sorting function (Carnoy, 1995). This screening process restricts access to further levels of education as well as future labour market participation by virtue of credentials that students obtain by completing whole programmes of study or certain sequences of courses to a predetermined level. The minimum credential is usually the secondary school leaving qualification while the maximum credential would be a terminal degree at the tertiary level (Killeen, Turton, Diamond, Dosnon, and Wach, 1999). Research shows that science attainment does not impact future wage rates as much as science achievement (Altonji, 1995). Nor does science achievement significantly impact students’ decisions to pursue tertiary academic education (Altonji, 1995).

119. For achievement to have a positive impact on labour market outcomes would mean that the higher students performed in science, the higher their rates of employment, economic productivity, and overall rate of return would be relative to their education. Research shows that students’ transition from school to work is influenced to some degree by their achievement and literacy in key academic subjects like science (Lamb and McKenzie, 2001; Luzzo, Hasper, Albert, Bibby, and Martinelli, 1999). In particular, students who demonstrate high achievement or high levels of scientific literacy, for example, tend to complete secondary school at higher rates than low performing students. And, students who complete secondary school tend to transition more smoothly to tertiary education or the labour market. But, there does not appear to be much additional labour market value to advanced or additional courses in science or other subjects (Altonji, 1995).

120. As far as translating either science attainment or achievement to labour market returns, research suggests that both of these academic outcomes are primarily influenced by either the actual or perceived labour market opportunities for students based on their gender, race, and socioeconomic status (Furlong and Biggart, 1999; Hanson, Schaub, and Baker, 1996; Khattab, 2003; Kincheloe, 1999; Lamb and Ball, 1999; Shu and Marini, 1998). While these non-schooling factors often overlap with schooling to influence students’ educational attainment and achievement, they are rarely if ever the result of schooling. In fact, in many nations culture is a significant influence on educational attainment and achievement (Sorensen, 1994). In statistical analyses, however, cultural effects generally get lost or overlap significantly with social stratification indicators. Consequently, gender, race, and socioeconomic status are frequently the focus of educational policies and school reforms because these indicators do not often ‘wash out’ of multivariate statistical analyses. They can also have a significant impact on the relationship between scientific literacy and the labour market because they largely determine students’ perceived or actual labour market opportunity (Ishida, Müller, and Ridge, 1995; Luzzo and McWhirter, 2001).

**Opportunity Structure**

121. The history of educational policy in most nations is marked throughout by overt attempts to reduce social stratification by gender, race, or socioeconomic status by making the link between schooling and the labour market more direct and overt (Breen and Whelan, 1993). While the success of social restructuring efforts through school reform have historically been limited or marginal at best, policymakers continue to see schooling as a way to mold students from diverse backgrounds into economically productive citizens. Much of the relevant research, unfortunately, does not indicate that schooling is always the best or sole venue for social restructuring related to labour market participation or productivity.
122. Research specifically shows that school-based courses and training related to future work do not impact labour market success as much as actual work experience that students receive from after-school jobs (Gustafsson, 2002; Hodgson and Spours, 2001). In addition, school-based connections to the labour market have been found to have little or no effect on students’ attitudes to their own positions in the labour market (Gustafsson, 2002). This suggests that science courses that make explicit connections to future work or labour market applications may not contribute to students’ sense of efficacy regarding their educational attainment, achievement, or labour market expectations as much as actual involvement in the labour market does. This does not mean that schools cannot provide students with any sense of their future place in the labour market—just that this influence is limited.

123. In fact, there is a body of literature outlining the effects of a ‘science pipeline’ that begins in schools and ends in the labour market (Berryman, 1983; Hanson et al., 1996). Research in this area measures the aspirations and expectations of students based on their perceived opportunities. This pipeline idea mirrors Bourdieu’s (1977) ‘habitus’ argument, which suggests that students model their own lives and aspirations on the ‘relative success or failure of like others in their environment’ (J. A. Jacobs, Karen, and McClelland, 1991). If students believe that a certain occupation or life course is possible to attain, then they may aspire to it. For example, if a 15-year-old girl learns in science class that there are female scientists doing important work in an area that interests her, she sees that ‘scientist’ is an option for her and is more likely to pursue science as a future career. The research suggests that when schools and science courses in particular give students opportunities to pursue science both in school and in the labour market, the students will be more inclined to do so (J. E. Jacobs, Finken, Griffin, and Wright, 1998).

124. Data from PISA could be used to identify any explicit institutional connections that may exist between schooling and the labour market (e.g. job placement services, corporate-sponsored vocational training, or business representatives teaching courses in schools). PISA could also provide data identifying any implicit connections between schooling and the labour market such as those suggested by the ‘science pipeline.’ Using this data on these explicit and implicit connections, researchers could assess or explain a nation’s opportunity structure for certain segments of the youth population.

Adolescents’ Aspirations and Expectations

125. There is a growing concern among policymakers that youth are leaving school and entering the labour market without sufficient interest in, concern for, and knowledge of science or the labour market to meet the current or future employers’ needs. In many nations, there has been a public lament over the perceived incompetence of each successive cohort of school leavers. This lament has been accompanied by policy reports that youth are unskilled, unaware, and uncaring regarding labour market needs in their respective nations (OECD, 1999). The public, policymakers, and industry spokespeople in the United States have been especially vocal in their concern over this perceived crisis (Wiseman, forthcoming 2005). Yet, there is relatively little empirical research that investigates adolescents’ aspirations and expectations, which could inform policymakers concerned with the relationship between students’ scientific interest in, concern for, and knowledge of the labour market. This is, therefore, an area in which PISA data could greatly contribute to educational research and policy.

126. The policy-relevant issues related to adolescents’ labour market aspirations and expectations include the following: school leavers’ work ethic, the importance that school leavers assign to their own achievement levels, the balance between students’ labour market aspirations and expectations, and their attitudes regarding schoolings’ ability to prepare them for the labour market. Data from PISA could be used to identify and explain each of these phenomena.
What little research there is on students' attitudes and expectations for their future labour market participation crosses the literature from several disciplines and theoretical perspectives (Albert and Luzzo, 1999; Lent, Hackett, and Brown, 1999). There is little research on adolescent's aspirations and expectations related to scientific literacy specifically, but research related to students' educational attainment and achievement has been published. Some studies suggest that there is a general idea that working hard in school is somehow the key to labour market success (Foskett and Hesketh, 1997; Lowe and Krahn, 2000). In particular, it has been shown that students both believe in and buy into the screening function of educational credentialism (Killeen et al., 1999).

Perhaps one of the most policy-relevant findings related to students' labour market aspirations and expectations and their attitudes on educational attainment and achievement comes from Sean Worth. Worth (2002) suggests that in the late 1990s there was an increase in the 'perceived importance of personal educational achievement found in young people's attitudes.' His research also found a relationship between students’ expected educational attainment and their expectations for future work. Thus, while gender, race, and class continue to be strong influences on students’ attitudes toward their educational attainment, achievement, and their expectations for future labour market participation, research suggests that there are relationships among attainment, achievement, and labour market expectations that are independent of gender, race, and class (Lent, Lopez, and Bieschke, 1991). In fact, Kelly (1993) found that academic achievement is a better predictor of career self-efficacy than gender.

Even when students’ academic achievement or attainment does not match their background (i.e. working class students who experience success in school or, in particular, science courses), those students will eventually develop aspirations that match their achievement or attainment levels (J. A. Jacobs et al., 1991). Of course, these students may adjust their aspirations as they mature as is often reflected in the lowered expectations for future labour market participation among older students. These older students’ labour market expectations are generally lower than their original aspirations suggested, but their optimism regarding these adjusted expectations indicates that they have matured in this respect (Powell and Luzzo, 1998).

In another study, students were asked directly what they thought employers looked for when hiring. Most students responded that employers were more concerned with positive work attitudes and behaviours instead of specific technical skills related to the job (A. Taylor, 2002). In addition, research further shows that students routinely believe that their secondary education has provided them with no relevant job skills or preparation for the labour market (Alromi, 2001; A. Taylor, 2002). This would suggest that students’ science-related education and achievement do not influence their attitudes about the labour market as much as a general education and an understanding of employability skills do.

In addition, research suggests that students’ labour market attitudes and aspirations are formed at relatively early ages based on both internal and external influences (Furlong and Biggart, 1999; Paa, 2000). This means that 15-year-olds may already have aligned their labour market aspirations with more realistic expectations for labour market participation, and that science-related education is not influential any more at this point. Yet, even though labour market aspirations may be formed earlier than 15, occupational aspirations are highly unstable during the elementary and secondary school years (Hall and Kelly, 1995; J. A. Jacobs et al., 1991; A. Kelly, 1989). As students pass through adolescence and enter early adulthood, their occupational aspirations evolve into more realistic choices as they are ‘buffeted by the experiences…in educational and employment settings’ (J. A. Jacobs et al., 1991).

IMPLEMENTATION

Following extended discussions with the Questionnaire Expert Group, consultations with the Science Expert Group and National Project Managers, and review of the empirical
outcomes of pilot and Field Trial data, the following constructs relating to science literacy
and the labour market were recommended to the PISA Governing Board for inclusion in
the PISA 2006 Main Survey.

133. The following constructs were measured with item batteries included in the student
questionnaire:

- Science course taking (current and previous year)
- Student’s career-oriented motivation to study and work in science.
- Student perceptions about the usefulness of science at school for labour market
  participation
- Student knowledge of science-related career opportunities
- Student’s expected job at age 30.

134. Items were included in the school questionnaire to measure:

- School-based activities related to the labour market
- The prevalence of out of school labour market training activities
- The influence of business and industry on the curriculum
- The extent to which pedagogical activities focus on preparing students for science-
  related careers
- The extent to which pedagogical activities focus on preparing students for tertiary
  education
- Opportunities and responsibility for career guidance at school

135. In addition the following constructs were measured in the international option\(^3\) of a parent
questionnaire:

- Parents' perceptions of student aspirations in the area of science
- Parents' perceptions of the importance of science for the job market

REFERENCES


International Higher Education, 8 (Summer), 4-5.

Chicago: University of Chicago Press.


\(^3\) Countries may choose whether to administer the parent questionnaire. It is not a core
component of the PISA study.


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**TEACHING AND LEARNING OF SCIENCE**

*Tina Seidel & Manfred Prenzel*

**ELABORATION**

136. An understanding of science and technology, and positive attitudes towards science, are essential to a young person’s preparedness for life in modern society (OECD, 2004). Being scientifically literate means being empowered for participation in a society that is strongly influenced by science and technology. The development of an understanding of science and positive attitudes towards science is vital for young people and in turn for the development of our society.

137. Science teaching means providing a learning environment in which young people have the opportunity to systematically engage in science activities and to develop scientific literacy. Science educators nowadays agree that the central task of teaching science in a way that aims at scientific literacy is the systematic development of three competencies: a) identifying scientific questions, b) explaining phenomena scientifically, c) using scientific evidence (Bybee, 1997a, 1997b; OECD, 2004). These competencies are of special relevance for future citizens in our society.
Science is a traditional part of the school curriculum. The understanding of science in conventional curricula often is influenced by the structure of the discipline and is, thus, more restricted than the conceptualisation of scientific literacy within PISA 2006. Nevertheless, one of the major goals of science teaching is to provide students with opportunities to develop science competencies as they are outlined by the PISA 2006 scientific literacy conceptualisation (OECD, 2004).

In the PISA 2006 contextual framework, teaching is elaborated upon from the perspective of the individual learners. From the perspective of the individual, teaching represents a special kind of learning environment, and it is embedded in different in-school and out-of-school sources of science knowledge. Young people encounter science and technology issues in many out-of-school activities. Out-of-school activities provide rich opportunities for authentic contexts in which science is applied. However, the availability of out-of-school science related activities depends on the resources of the family which leads to unequal opportunities for children. One challenge of teaching is to address differences in student pre-requisites and to support the systematic and intentional learning of science for every student. This includes fostering the understanding of science as a mode of understanding the world by identifying scientific questions, explaining phenomena scientifically and using scientific evidence.

For the first time, PISA in 2006 encounters the area of teaching and learning applying a domain-specific approach. So far, PISA has been interested in out-of-school factors (e.g. family resources) that show an impact on the young person’s literacy development. In-school factors have been investigated only on the more general level of teaching and schooling. The focus on domain-specific aspects of science teaching and learning takes up a neglected area of research on teaching effectiveness (Seidel & Scheerens, in prep.) and, thus, will significantly contribute to the further development of the field. However, with respect to the goals and design of PISA 2006, two major aspects have to be considered.

Firstly, PISA measures “knowledge and skills for life” and does not have a strong focus on curricula. This extends the scope of the research since specific curricular topics are not at the centre of investigation. Moreover, it makes room for questions on the relationships between in- and out-of-school sources of science information, science teaching activities, and the nature of science that is represented in teaching.

Secondly, PISA students are randomly sampled within schools, not from intact classrooms or grades. This means that no relationship between teaching and learning at the level of the classroom can be examined. However, conclusions can be drawn on the relationship between teaching and learning at the levels of individuals, schools and countries.

**Neglected areas in research on science teaching and the consequences for PISA 2006**

Reviews on teaching and learning point out several general teaching components that have a high impact on student learning (Brophy & Good, 1986; Creemers, 1994; Doyle, 1986; Fraser et al., 1987; Scheerens, 2000; Scheerens & Bosker, 1997; Scheerens et al., 2005). The most prominent indicators for effective teaching are the opportunity to learn / learning time, goal-oriented and structured teaching, interactive and cooperative learning, cognitive challenge, support, feedback, and learning to use learning strategies. In addition, a review of the research of the last decade (1994-2004) has shown evidence for distinctive trends in teaching effectiveness research that are closely associated with shifts in theories on teaching and learning (Scheerens et al., 2005; Seidel & Prenzel, 2004b). These can be outlined as follows:

- Integration of single instructional activities into instruction syndromes / patterns
- Focus on learning processes as mediators between teaching and learning
- Consideration of multiple output criteria and cumulative learning

One of the major challenges is to establish a profound theoretical framework on processes of teaching and learning. Therefore, teaching indicators should be integrated into central
components of teaching and learning (Seidel & Scheerens, in prep.). Central components refer to the setting of goals, the orientation of learners towards goals, the execution of learning activities, and the evaluation, monitoring and regulation of learning (Artelt et al., 2003; Bolhuis, 2003; Bransford et al., 2000). Components of learning refer to situations of intentional learning, and teaching is one of the major settings in which intentional science learning is carried out.

Furthermore, domain-specific learning plays a prominent role in current models of teaching and learning (Seidel & Scheerens, in prep.). Generally, teaching has to provide opportunities for students to orient their learning activities towards a deep conceptual and procedural understanding of learning content. In science teaching these are determined by the nature of science: by inquiry and scientific investigations, by using science as a model and representation format, and by applying science to real-life situations (Duit & Treagust, 1998; Harlen, 1999; Hofstein & Lunetta, 2004; Mintzes et al., 1997). To a large extent, teaching effectiveness research has neglected research on the domain-specific components of teaching and learning. However, science studies that are focused on domain-specific components show substantial effects on student learning (White & Frederikson, 1998). Thus, PISA 2006 is taking up a neglected area of teaching effectiveness research with positive empirical evidence for its relevance to science learning.

Teaching effectiveness studies apply rather heterogeneous research designs and are associated with different research paradigms (Scheerens et al., 2005; Seidel & Scheerens, in prep.). Four criteria can be used to differentiate between types of studies on instruction effectiveness. These are sample size, research design, points of measurement, and analysis methods. By combining these criteria, three different types of research studies emerge: a) cross-sectional large-scale surveys with a correlational design and the application of multi-level analysis methods, b) quasi-experimental intervention studies with a pre-post-test design, and c) longitudinal (intervention) studies with a well-controlled multi-test design. PISA 2006 is within the first type of research study. Compared to other studies in the field, PISA 2006 will provide data on teaching and learning by applying high-level methodological standards, control for background variables, and a high-level scaling of output measures. The design is limited with respect to the empirical evidence on the influences of instruction on learning outputs. The design does, however, allow comparisons of teaching patterns within and between countries, an analysis of teaching cultures within schools, and the investigation of the relationships between in-school and out-of-school factors on an individual analysis level. Participating countries have the possibility of obtaining data on predominant styles of science teaching.

In addition, the heterogeneity of the field is determined by differences in the quality of assessment instruments. Teaching effectiveness research shows a broad variety of instruments, ranging from the systematic variation of teaching in experimental settings to the application of teacher questionnaires, student questionnaires, classroom observations and systematic video analyses (Scheerens et al., 2005). Thereby, it can be shown that information on teaching is valid and reliable if research methods focus on the behaviour, activities and descriptions rather than on general qualitative opinions and impressions (Clausen et al., 2003). Student questionnaires are the most prominent research method and can show substantial effect sizes of variables of interest on student learning (Seidel & Scheerens, in prep.).

In summary, PISA 2006 is taking up neglected fields of teaching effectiveness research by investigating domain-specific components of science teaching and learning. The design of PISA has some limitations with respect to overall explanatory power in this field but will yield significant insight into differences between countries and schools in predominant teaching patterns and science teaching cultures. The assessment of science teaching and learning will be based on instruments with a descriptive character of science activities. Student questionnaires are suitable in the context of the PISA 2006 assessment instruments.
MODEL OF TEACHING AND LEARNING

149. A basic model on teaching and learning is proposed (Seidel & Prenzel, 2004a, 2004b). The model allows the area of science teaching and learning to be related to the other components of the PISA 2006 contextual framework. The basic model summarises the current state of the art in teaching and learning. Four basic components are distinguished: 1) the impact of student pre-requisites on all components of teaching and learning, 2) teaching that provides opportunities for the students to engage in science, 3) the students’ perception, acknowledgement and processing of science-related information that is provided by teaching (motivational and cognitive processes), and 4) the students’ development of scientific literacy.

![Figure 1: Basic model of teaching and learning](image)

150. As a conclusion of previous reviews (Brophy, 2000; Fend, 1998; Helmke, 2003; Reusser & Pauli, 2003; Shuell, 1996; Wang et al., 1993), the basic model builds on six assumptions:

- Teaching and learning is highly determined by the students’ individual pre-requisites
- Teaching is characterised by the orchestration of different activities, thus representing patterns rather than unrelated activities
- The quality of the orchestration provides opportunities for the students to actively and intentionally engage in science learning activities
- The degree to which students use teaching as a source for science learning depends on their individual perception of supportive learning conditions, the quality of their learning motivation, as well as the application of deep learning strategies
- Learning outputs are multiple and comprise cognitive and non-cognitive components.

151. In PISA 2006, three science-teaching areas are of special interest for the students’ development of science competencies. These are:

- Opportunity to learn science: teaching as a source of science information
- Interactive teaching and learning
- Nature of science teaching

152. In the following section, these areas are going to be elaborated upon in more detail. For each area, the theoretical background and state of the art is summarised, followed by findings on the relationship to students’ learning processes and learning outputs.
The first area of science teaching and learning refers to the sources from which young people can draw science information for learning. Sources for science learning comprise different areas in which young people are actively engaged in science-related issues and that have a high relevance for their personal life. School represents an important source of information, next to families and friends. Furthermore, media and institutions such as TV, newspaper, radio, the Internet, science books, science museums, and science centres play an important role in engaging young adults in science-related issues (Cross & Fensham, 2000).

Sources of science information represent opportunities for science learning and for the development of scientific literacy. The relationship between sources of information and scientific literacy is mutual. School, family, friends, media, or the Internet represent learning opportunities to engage in science-related issues. At the same time, these areas also represent possibilities for young people to apply science knowledge in different situations. The PISA 2006 contextual framework is focused on the first aspect with regard to the teaching and learning of science. It is assumed that sources of science information represent opportunities for students to develop scientific literacy. The research interest is in comparing the different in-school and out-of-school sources of science knowledge with respect to
- differences in sources of science knowledge between science topics,
- differences in sources of science knowledge between countries,
- the relationship between sources of science knowledge and the students’ individual pre-requisites such as their prior knowledge, their home situations, their relationships with friends and their socio-economic status.

Research on science teaching has largely neglected the field of comparing different sources of science information. Despite the fact that an integration of in- and out-of-school factors has been claimed repeatedly (Prenzel et al., 1999; Prenzel & Renkl, 2002), the majority of research studies either focus on in-school or on out-of-school conditions. However, studies that investigate the relationship between both sources show that the family’s support of science is an important predictor for how the student finds relevance in science topics taught in school. Furthermore, teaching also plays an important role in compensating for any lack of supportive conditions within families (George & Kaplan, 1998; Ho & Willms, 1996; Schwindt, 2004).

School as a source of science knowledge and the role of teaching time on student learning has been intensively investigated in teaching effectiveness (Scheerens & Bosker, 1997). A recent review of research studies (Scheerens et al., 2005) shows a corroboration of the previous findings, indicating that diverse opportunities to learn in school support the students’ motivation to learn, the application of deep learning strategies, and the positive development of competencies and attitudes towards domains. However, most of the studies refer to the domain of mathematics or reading (Arnold et al., 2002; Hill & Rowe, 1998; Kupermintz et al., 1995; Kyriakides et al., 2000; Muijs & Reynolds, 2000; Reezigt et al., 1999). Only a few recent studies have taken up the role of opportunities to learn in science teaching (Burkam et al., 1997; Nolen, 2003; Seidel, 2003; Seidel et al., 2002).

Seidel et al. (2003, 2002) have shown that students value science learning if their teachers effectively use the available teaching time. In such teaching situations the students report being supported to learn science, they are more intrinsically motivated to learn and apply deep learning strategies when engaging in science activities. In the study of Nolen (2003), a positive effect of the use of teaching time on the students’ long-term development of positive attitudes towards science was found. Thus, positive effects with respect to the students’ motivation to learn science and their attitudes towards science have been shown.
Interactive science teaching

158. The second area of the PISA 2006 contextual framework with regard to the teaching and learning of science refers to interactive (versus transmissive) science teaching. Science educators nowadays agree on an orientation of teaching towards interactive learning activities (Hofstein & Lunetta, 2004). Traditional science teaching has a strong focus on transmitting science knowledge through lectures, textbooks and demonstrating experiments. Interactive science teaching is, in contrast, oriented towards cooperative learning, student discussions and collaborative teacher-student interactions.

159. The degree to which interactive teaching is implemented in classrooms differs between countries and is strongly related to cultural beliefs about good teaching practices. The TIMSS 1999 video study showed systematic differences in interactive mathematics teaching between countries with high achievement rankings (Hiebert et al., 2003). Australia, Japan, the Netherlands and Switzerland show a stronger orientation towards interactive teaching methods. Hong Kong and the Czech Republic are more likely to apply teacher-centred methods.

160. In science teaching, differences between countries in interactive teaching are to be expected. Scientific investigations and student experiments represent an important difference to mathematics instruction. Previous findings give an insight into the implementation of interactive versus transmissive science teaching (Baumert & Köller, 2000; Seidel & Prenzel, 2004a). For example, a video analysis of German physics instruction (Seidel & Prenzel, 2004a; Seidel et al., 2002) revealed teaching approaches that varied between “chalk-loaded” demonstration lessons (in which physics knowledge is transmitted by teacher talk, class work and demonstration experiments) and student experiment lessons (in which interactive elements are implemented and students cooperatively work on and discuss experiments).

161. The studies applying student questionnaires give evidence in favour of interactive teaching (Scheerens, 2000; Scheerens & Bosker, 1997). A review of the effects of cooperative and interactive science teaching shows positive effects on student learning (Scheerens et al., 2005). Interactive science teaching has a positive impact on the students’ learning motivation, learning strategies, the development of science competencies and positive attitudes towards science.

162. Reviews have also pointed out the positive effects of direct and transmissive teaching on student learning (Chang & Barufaldi, 1999; Seidel, 2003; Seidel et al., 2002; Stolarchuk & Fisher, 2001), indicating that interactive and direct teaching should be regarded more as complementary rather than as contradictory positions. In the following section, some of the studies showing the positive effects of interactive teaching on science learning will be outlined.

163. In science teaching, Sumfleth et al. (2004) have compared traditional chemistry teaching with interactive teaching. They were able to show a positive impact in favour of interactive science teaching. Students in interactive classrooms showed a deeper understanding of chemistry contents than students in traditional classrooms.

164. Borsch et al. (2002) have shown the positive effects of cooperative learning on students’ achievement in science. The results of the study show a substantial increase in declarative knowledge in the cooperative classes. Thereby, students at all levels of prior knowledge profited from the interactive teaching method.

165. Interactive teaching in biology has been investigated in a study by Lazarowitz et al. (1996). Two experimental classes were instructed with interactive methods, and two comparison classes with individualised learning. The findings show that students in interactive classrooms have higher scores in self-esteem, attitudes towards biology and the perception of supportive classroom conditions. Furthermore, interactive classes resulted in better knowledge development than individualised classrooms.
166. In mathematics teaching, further evidence of interactive teaching methods is provided. Ginsburg et al. (1998) showed in an experimental study that students who participated in peer collaboration scored higher in measures of computation and word problems. Furthermore, they reported higher levels of academic motivation and social competence than students who did not participate in peer collaboration.

167. In reading, Chinn et al. (2001) were able to show that collaborative reasoning and discussion produces greater engagement and a more extensive use of higher-level cognitive processes compared to traditional recitation teaching. Moreover, Steven and Slavin (1995) found positive long-term effects for cooperative teaching methods, compared to matched control schools, on the students’ reading and writing achievement and their learning strategies over a time span of two years.

**Nature of Science Teaching**

168. Since learning is defined as a constructive and self-regulatory process of the individual learners (Bransford et al., 2000), teaching can only offer opportunities for the students to actively and intentionally engage in science learning. First, teaching can represent an important source of science information and can offer time for the students to engage in science-related activities. Second, science teaching can provide various methods for the students and teachers to interact and to cooperate. Third, science teaching in school represents a specific knowledge domain and, thus, has to integrate young people into the field of science.

169. The third area of the PISA 2006 contextual framework with regard to the teaching and learning of science draws on domain-specific aspects: the nature of science teaching. According to the state of the art in science education (Bybee, 1997a, 1997b; Duit & Treagust, 1998; Harlen, 1999; Hofstein & Lunetta, 2004; Mintzes et al., 1997), the nature of science teaching is characterised by three main aspects:

- Inquiry and scientific investigations
- Using science as a model and representation
- Applying science to real-life situations

**a) Inquiry and scientific investigations**

170. Inquiry and scientific investigations have been intensively investigated in science education (Hofstein & Lunetta, 2004). In the research literature science educators differentiate between “inquiry learning” as a systematic approach to understanding scientific investigations and “student work and experiments” which are limited to the phase of hands-on activities. Overall, a substantial impact on the students’ understanding of science and about science has been shown. The review of recent inquiry studies gives clear positive evidence for its impact on students’ science knowledge. Of the 29 studies that have investigated inquiry learning in science, 25 findings give positive evidence (Scheerens et al., 2005). Heterogeneous findings, however, are found for student work and student experiments. The quality of how science is represented by inquiry and scientific investigations is of higher importance than the implementation of student experiments per se (Harlen, 1999). Some of the studies that give insight into the relevance of inquiry and scientific investigations will now be outlined in more detail.

171. Clear evidence for the effects of inquiry on the students’ learning of science is given by the study of White & Frederikson (1998). The goal of the study was to develop an instructional theory, curricular materials and a teaching approach to make scientific inquiry accessible to all students, including younger and lower-achieving students. The teaching approach helped students to develop knowledge about science through a process of scaffolded inquiry, reflection, and generalisation. The students improved significantly in both physics and inquiry assessments, as well as with regard to their attitude towards science. Furthermore, the inquiry approach was particularly beneficial for low-achieving students.
students. The performance in their inquiry test was significantly closer to that of high-achieving students than was the case in the control classes. Thus, the inquiry approach had the valuable effect of reducing the educational disadvantage of low-achieving students while also being beneficial for high-achieving students.

172. George and Kaplan (1998) investigated the role of science activities on students’ attitudes towards science. Using data from the base year survey of the National Educational Longitudinal Study of 1988 (NELS:88), they succeeded in showing that science activities have a significant positive direct effect on science attitudes. The results also pointed out that the availability of science facilities in schools was strongly connected to the frequency of science experiments.

173. Conversely, Hamilton et al. (1995), as well as Baumert & Köller (2000), reported heterogeneous findings on the role of science experiments. Both studies showed no significant effects of science experiments on the students’ achievement in science. However, positive relationships between student experiments and the students’ interest in science were found in the study of Baumert & Köller (2000).

174. Furthermore, differences between genders in scientific investigations have been investigated. Burkam et al. (1997) also used the NELS:88 data base to identify gender differences in science learning. They were able to show that hands-on lab activities continued to be related to all students' performance, but especially to girls'. The findings suggest the importance of the active involvement of students in the science classroom as a means of promoting gender equity. However, Jovanovic & King (1998) examined whether, over a school year, boys and girls equally perform hands-on science activities (e.g., manipulating the equipment, directing the activity, observing). In addition, they examined whether the frequency of hands-on activities accounted for changes in boys' and girls' science attitudes at the end of the school year. The results indicated that being actively involved in hands-on science activities predicted students' end-of-the-year science attitudes. However, boys and girls did not participate equally in these activities. Moreover, it was found that girls, and not boys, showed a decrease in science ability perceptions when they were involved in hands-on science activities, suggesting that boys and girls experienced these activities differently.

b) Science as models or representations

175. Science as a model or representation is the second aspect of the nature of science teaching. In general, it is assumed that models and representation formats help students to understand complex and abstract concepts. Overall, the positive effects of science as models or representations on the students’ knowledge of science and about science have been observed (Scheerens et al., 2005). However, in the last decade none of the studies have addressed the effects on attitudes towards science. In the following section, studies on science as a model are outlined. Additionally, studies with a focus on the role of representation formats are summarised.

176. Hogan (1999) has addressed the question of building mental models of the nature of science in a experimental intervention, called Thinking Aloud Together. Students who received the intervention gained in meta-cognitive knowledge about collaborative reasoning and in their ability to articulate their reasoning processes, in comparison to students in control classes.

177. In the study of White & Frederikson (1998), the impact of the computer-based instrument ‘ThinkerTools’ was shown. The researchers assume that computer-based instruments can serve as tools to create optimal experimental conditions. In the intervention study, students worked with ThinkerTools on principles of force and motion. It was shown that ThinkerTools supported students in engaging to learn about and reflect on the processes of scientific inquiry as the students constructed increasingly complex models of force and motion phenomena.

— 54. —
Furthermore, research studies point out the relevance of structure in implementing models and representations in science teaching. In the study of Kramarski & Mevarech (1997), the effect of meta-cognitive training as a structuring element was investigated using the problem-based Logo environment. The environment aimed at facilitating the students’ ability to construct graphs and reflect on their learning. In an experimental design, classes were randomly assigned to one of two treatment groups (meta-cognitive training, control). Although no significant differences were found between groups prior to the beginning of the study, but at the end of the study the students in the meta-cognitive treatment classes constructed graphs better than the students in control classes. The meta-cognitive group was also better able to reflect on their learning.

In the studies of Hardy et al., (2004) and Möller et al., (2002) different representation formats and their effects on science understanding were investigated. Thereby, the role of structure was taken into consideration and two conditions were systematically varied. One group of students worked with an integrated and structured format (experimental) and the other group constructed representations with an open and unstructured format (control). The findings indicated an advantage of the integrated representation format for the students’ conceptual understanding of science. Similar to these findings, Einsiedler & Treinies (1997) were able to show that fourth graders are already able to acquire higher levels of biology understanding when using different representation formats.

c) Science as real-life applications

Science as real-life applications represents the final focus of the PISA 2006 contextual framework with regard to the teaching and learning of science. Young people encounter science and technology in different environments; very often they encounter science in out-of-school activities. Out-of-school activities provide rich opportunities for authentic contexts in which science is applied. Science educators agree that the challenge in teaching is to address different student pre-requisites and to support a systematic and intentional learning of science. Science represents a mode of understanding the world by identifying scientific questions, explaining phenomena scientifically and using scientific evidence (Bybee, 1997a, 1997b). At the same time, teaching has to address real-life applications to help young people in their development of scientific literacy in everyday science-related applications.

Research on science education has addressed real-life applications in traditional science teaching as well as in new curricula and integrated teaching approaches with a focus on authentic contexts and real-life applications (Bennett et al., in press). Furthermore, constructivist teaching approaches usually address the relevance of real-life applications as a means of creating authentic and meaningful contexts for learners (Collins et al., 1989). Finally, technology-based studies have been conducted that address the role of authentic contexts in knowledge construction (Bransford et al., 2000).

Generally, real-life applications do not represent a major focus in traditional science teaching (Seidel, 2003; Tesch, 2004; Widodo, 2004). Seidel (2003), for example, has analysed the teacher and student statements in physics discourse patterns with respect to the role of real-life applications. She succeeded in showing that reference to real-life applications occurred only in 9% of the lesson time. However, the classes in which real-life applications were addressed varied between 1% and 19% of lesson time, indicating remarkable differences between classrooms.

With respect to constructivist teaching approaches, positive relationships between authentic contexts / real-life applications and student outputs have been shown. Labudde, for example, has investigated a constructivist approach in physics instruction at the upper secondary level in Switzerland (Labudde, 2000; Labudde & Pfluger, 1999). The findings show systematic positive correlations between real-life applications in teaching and the students’ physics interest, as well as (for some variables) the students’ TIMSS achievements.
184. Ramsden (1997) investigated the effects of the context-based approach ‘SALTERS’ on student learning, compared to traditional chemistry teaching. In the study, a range of diagnostic questions for students, following both a context-based approach and a more traditional approach to high school chemistry, were addressed. The findings indicated only a small difference between groups in levels of understanding, but that there were some benefits associated with a context-based approach in terms of stimulating the students’ interest in science. Furthermore, heterogeneous findings on the effectiveness of new curricula and context-based teaching approaches on science competencies and attitudes have recently been reported by the Chemistry-in-Context (ChiK) approach (Fey et al., 2004; Gräsel, 2005).

185. To summarise, the findings on real-life applications in science show a positive impact on the students’ motivation to learn and their attitudes towards science. With respect to science knowledge, heterogeneous findings have been reported. Programmes that have developed new curricula, teaching approaches and technology-based instruments on the basis of real-life applications indicate that the implementation of these programmes in regular science teaching has to be taken carefully into consideration. Thus, real-life applications are not a fast-selling item, but have to be seen in the light of the quality of science teaching as a whole.

**IMPLICATIONS**

186. The PISA 2006 contextual framework elaboration on the teaching and learning of science has been oriented towards a review of studies that present empirical evidence on the impact of teaching on science learning. The restriction of this review of studies that met this criterion has limited the amount of studies included. A systematic review and research synthesis of teaching effectiveness studies of the last decade served as a basis (Scheerens et al., 2005; Seidel & Scheerens, in prep.) for summarising the state of the art in science teaching.

187. For the systematic review of Scheerens et al. (2005), broad searches of the literature on instruction effectiveness in the domains of mathematics, reading and science were conducted. Overall, 317 publications matched the chosen keyword combinations. Taking into account the number of studies that empirically related teaching to student outcomes, the number of published articles was reduced to 107. Thus, the literature searching process indicated that a large number of studies in the last decade did not apply empirically and evidence-based research methods to relate teaching to student outcomes.

188. Despite the fact that the number of studies included was restricted, it was shown that the nature of science teaching matters, especially if domain-specific components are taken into consideration. The studies emphasised the positive impact of science teaching on student learning in three major areas:

- Science teaching as an opportunity to learn and as a source of science knowledge
- Science teaching as an opportunity to interact with students and teachers in science-related topics
- Science teaching as an opportunity to learn about the nature of science: about inquiry and scientific investigations, about science as model and representation, about science in real-life applications.

**Potential Policy Issues**

189. The following policy questions in this area could be addressed by PISA 2006:

*Country level*

190. First, PISA could investigate the cultural patterns of science teaching approaches and give an insight into differences between countries with regard to these styles. How much do
countries vary in their teaching approaches? Are there culturally shared patterns of science teaching with regard to school as a source of science knowledge, interactive teaching, and the nature of science?

191. Second, interrelations between the three areas of science teaching and learning might be of interest. To what extent do the three areas represent a common teaching approach within countries? Is interactive science teaching related to the nature of science in teaching? Does this have an effect on the students’ use of learning opportunities within school settings? How do countries differ with respect to these interrelations?

192. Third, the relationship between science teaching patterns and student science learning on a national level could be taken into consideration. Are students in countries with high quality science teaching more likely to develop a positive attitude towards science and do they show a better knowledge of and about science? Are they more likely to develop positive attitudes towards science if teaching is oriented towards interactive elements and towards authentic and real-life applications of science? Do inquiry and scientific investigations lead to a better understanding of science, in the sense of scientific knowledge and knowledge about science?

School level

193. On the school level, the question of school type or school-specific patterns of science teaching may be approached. Are there systematic differences in science teaching approaches between different types of schools or different locations of schools?

194. The relationship of school-specific science teaching approaches to other school level variables could be taken into account. Are specific patterns in science teaching related to school profiles, their resources or their autonomy?

195. Moreover, the extent to which specific patterns of science teaching are related to the composition of the school population concerning, for example, the socio-economic status of the students could be explored.

196. Finally, if school-specific teaching patterns are identified: What impact does a school’s orientation to science teaching have on the students’ scientific literacy?

Individual level

197. On the individual level, the compensatory effects of science teaching on student achievement might be taken into consideration. Does science teaching play a compensatory role for low SES-students in providing opportunities to encounter science-related issues and to systematically learn science? Does interactive science teaching with a focus on the nature of science provide manifold learning opportunities for students with high and low pre-requisites (such as SES, parental involvement, gender, etc.)? How do high and low pre-requisite students perceive science teaching and learning at their school?

IMPLEMENTATION

198. Following extended discussions with the Questionnaire Expert Group, consultations with the Science Expert Group and National Project Managers, and review of the empirical outcomes of pilot and Field Trial data, the following constructs relating to science literacy and the labour market were recommended to the PISA Governing Board for inclusion in the PISA 2006 Main Survey.

199. The following constructs were measured with item batteries included in the student questionnaire:

- Source of science information (schools, media and information resources, family, friends)
- Interactive teaching of science
• Hands-on science activities at school
• Designing and applying scientific investigations
• Science as applications

REFERENCES


62.
SCIENTIFIC LITERACY AND THE ENVIRONMENT

Rodger W. Bybee

ELABORATION

200. Being scientifically literate contributes to an individual’s full participation in society. The understanding and abilities associated with scientific literacy empower those individuals to make personal decisions and appropriately participate in the formulation of public policies that impact their lives. Assertions such as these provide a rationale of scientific literacy as the central purpose of science education. Too often, however, the rationale lacks connections that answer questions such as ‘personal decisions—concerning what?’, ‘fully participate—in what?’ or ‘formulate policies—relative to what?’ One could answer these questions using contexts that citizens daily confront; for example, personal health and natural hazards. One other domain essential to individuals and countries is the environment.

201. Environmental issues are a global concern. Human activities such as the accumulation of waste, fragmentation or destruction of ecosystems, and depletion of resources have had a substantial impact on the global environment. As a result, threats to the environment are prominently discussed in the media, and citizens of every nation are increasingly faced with the need to understand complex environmental issues. The noted scientist Edward O. Wilson summarises the situation using an economic metaphor:

> What humanity is inflicting on itself and Earth is, to use a modern metaphor, the result of a mistake in capital investment. Having appropriated the planet’s natural resources, we chose to annuitize them with a short-term maturity reached by progressively increasing payouts. At the time it seemed a wise decision. To many it still does. The result is rising per-capita production and consumption, markets awash in consumer goods and grain, and a surplus of optimistic economists. But there is a problem: the key elements of natural capital, Earth’s arable land, ground water, forests, marine fisheries, and petroleum, are ultimately finite and not subject to proportionate capital growth (Wilson, 2002, p. 149).

202. Wilson’s use of an economic metaphor was deeper and more insightful than it may seem. Often, citizens will hear economic arguments for continued use of resources and destruction of environments. What Wilson’s metaphor points out is the need to understand scientific ideas such as renewable and non-renewable resources and the capacity of ecosystems to degrade waste. Stated succinctly, understanding issues of ecological scarcity directly influences economic stability and social progress. Ecological scarcity directly relates to environmental issues and a citizen’s scientific literacy.

203. A scientifically literate individual has more than knowledge of environmental issues. A scientifically literate individual also must have attitudes that contribute to actions. Although not totally unrelated to civic attitudes and values, the attitudes referred to here are grounded more in an understanding of the environment and less in democratic values. Examples of values associated with the environment include conservation, prudence, and stewardship (Kollmuss and Agyeman, 2002; Morrone, et al., 2001; Tikka, et al., 2000). This discussion will, therefore, address the following basic questions regarding scientific literacy and the environment:

- Knowledge and the environment: What do students know about the environment and environment-related problems?
- Attitudes and the environment: What influences students’ attitudes about the environment, and what attitudes do students hold about the environment?
- Behaviours and the environment: Do students engage in pro-environmental activities?

204. Discussions of these three themes, largely based on a review of the literature on environmental education, provide insights for a variation to a question central to the PISA
2006 scientific literacy framework—What do 15-year-olds know, value, and do in situations involving science-related environmental issues?

205. By extension, this discussion supports the inclusion of environmental and resource issues in the PISA 2006 assessment as a way of understanding what 15-year-olds know, value, and do relative to environments and resources, and as a way of improving our knowledge about how students come to know what they know, value what they value, and do what they do.

Students’ knowledge and the environment

206. Students must have scientific knowledge to understand environmental problems and their causes. Many suggest that environmental knowledge goes beyond an understanding of the environment. Students also should understand the effects of their actions on the environment (Morrone, et al., 2001). In addition to scientific knowledge students also need to know how they can lower their impact on the environment. Without exposure to action strategies, students lack the skills to bring about change. Individuals are unlikely to use their environmental knowledge if they don’t know how they can make a difference.

207. Palmer (1993) reported on the nature and development of young children’s early knowledge and awareness of environmental issues. Her study included children in the U.K. and U.S.A. and found that pre-school children knew a good deal about the natural world and ideas such as snow melting, that could relate to larger environmental issues such as global warming. This said, she also found that children have confused and inaccurate understandings about the environment.

208. Anderson and Moss (1993) investigated the origins of negative perceptions and poor understandings of wetlands. They found that young children (ages 6 to 7) had more positive perceptions than older children (ages 10 to 11). These data lead to the conclusion that the negative perceptions were not innate, rather they were learned. This finding has implication for education.

209. A Finnish study of fourth-graders demonstrated significant improvement in knowledge of the environment after experiencing inquiry-oriented activities and familiar environmental contexts (Aho, Huopio, and Huttunen, 1993).

210. Boyes and Stanisstreet (1993) investigated students’ (ages 11 to 16) perceptions about the ‘Greenhouse Effect.’ Not surprisingly, they found that students do understand some scientific ideas; but given specific issues, they demonstrated misconceptions and confusion. They suggest that students are aware of environmentally ‘friendly’ and ‘unfriendly’ actions and they understand many ideas, but they do not link particular causes with particular consequences. Rather, students generalise broadly; for example, students often think that any environmentally friendly action helps resolve all problems.

211. In a Spanish study conducted with older students (pre-university and university students) Gomez-Grannell and Cervera-March (1993) found that students’ knowledge about energy and the environment was superficial, and their awareness of the environmental consequences of certain actions was low. Finally, they reported that the media sensitised students’ opinions, but it did not increase their understanding of the environment.

212. Joy Palmer and her colleagues (Palmer, et al., 1998) investigated influences on the development of adults’ environmental knowledge and concern in the U.K., Slovenia, and Greece. The important findings from this research centred on providing young people opportunities for positive experience with the environment.

213. In summary, the research indicates that students do have nascent ideas basic to understanding environmental issues, but they also hold misconceptions about the environment. Further, students’ ideas about actions that might improve the environment also are inaccurate, and they generalise too broadly. The research indicates that experiences such as inquiry-oriented activities in familiar contexts may leave students...
with more accurate conceptions, positive perceptions, and pro-environmental behaviours. The one other bit of evidence worth noting is the media’s contribution to students’ understanding of the environment.

**Students’ attitudes and the environment**

214. Many environmental problems result from people’s behaviour and patterns of thought. Understanding the relationship between the attitudes people have toward the environment and the factors that influence those attitudes helps explain their behaviours (Tikka, et al., 2000). This section begins with a discussion of factors affecting environmental attitudes. In the latter part of the section, discussion turns to literature aimed at describing the environmental attitudes (and behaviours) themselves.

215. Children’s attitudes toward the environment are often correlated with talking about the environment at home, experiences with nature, and watching or reading about nature (Eagles and Demare, 1999). Similarly, adult environmental educators in three European countries indicated that the role of family and childhood experiences with nature were most influential in developing their concern for the environment (Palmer, et al., 1998).

216. A study completed in Finland investigated attitudes toward the environment held by students in different institutions of higher education. In general, female students showed more responsibility toward the environment than male students. An interesting variation in this study involved assessment of student groups where they found that biology students exhibited the most positive attitudes, the greatest levels of knowledge, and participated in more nature-related activities. In contrast, there was some evidence that students enrolled in programmes related to technology and economics adopted more negative attitudes toward the environment. Attitudes, participation in nature-related activities, and knowledge had a correlation in this study (Tikka, Kuitunen and Tynys, 2000).

217. In a different study, but related theme, Hodgkinson and Innes (2001) completed a study on the attitudinal influences of career orientation in university students. Not surprisingly, students in biology, sociology, and environmental studies displayed stronger positive attitudes toward the environment when compared to other disciplines; for example, law, business, and computer sciences. In Korea Choi and Cho (2002) completed a study that produced evidence that placing science in an ethical context can improve attitudes toward it.

218. Alicia Weaver completed a five-country comparison on determinants of environmental attitudes (Weaver, 2002). The countries were the United States, Great Britain, West Germany, Russia, and Japan. She found that pro-environmental attitudes—about both the consequences of human actions and the consequences of environmental problems on human health—are correlated with belief in the sacredness of nature, liberal values, some forms of environmental and scientific knowledge. This finding occurred in all countries studied, with some variation in significance and direction of influence.

219. Here, we turn to several studies that address differences and similarities with respect to environmental attitudes themselves. A study by Bjerke, Odegardstuen, and Kaltenborn (1998) investigated attitudes toward animals among Norwegian adolescents. Bjerke et al. used seven sub-scales which included: Humanistic, Moralistic, Ecologist, Naturalistic, Negativistic, Dominionsist, and Utilitarian. Adolescents rated highest on the sub-scales of Humanistic (e.g. they liked pets) and Moralistic (e.g. they were against zoos and cruelty to animals). Of importance for this discussion is the finding that Ecologist attitudes (e.g. they wanted to learn more about how species coexist) rated third highest in the survey. However, younger children (e.g. grade three) expressed more ecological interests than did students from grades six and eight. Fourth highest was the Naturalistic (e.g. they would choose a campsite where wild animals could be seen). Again, however, these attitudes decreased significantly with increasing age, and boys obtained a significantly higher score than girls.
Zheng and Yoshino (2003) reported cultural differences evidenced in a correspondence analysis of the data from a survey of Attitudes Toward Nature and Environment (ATNE). They explored the structural characteristics of response patterns to the ATNE in Japan, USA, and five European nations—France, Germany, Great Britain, Italy, and the Netherlands. This longitudinal study was conducted from 1953-1998 and showed significant changes in Japanese attitudes toward nature. For example, attitudes toward ‘conquering nature’ decreased in time while attitudes toward ‘follow nature’ increased. In general, the investigations attributed the changes to socio-cultural influences; for example, development of the economy, extension of industrialisation, and increased environmental accidents.

In the correspondence analysis, Zheng and Yoshino found that the cross-national survey resulted in the clusters of 1) USA and Italy as the two countries that tend to answer the most positive options to the three items—‘follow nature,’ ‘energy conservation is very important,’ and ‘environmental preservation is very important,’ 2) Britain, the Netherlands, and Germany tend to give half positive and half negative responses. In contrast to the USA and Italy these countries supported the attitudes of ‘make use of nature,’ while accepting ‘environmental preservation is very important’ and ‘energy conservation is very important.’ Finally, Japan and France tended to give negative opinions for the aforementioned attitudes.

Expression of attitudes toward nature and the environment correlated with the respondent’s social position, educational level, and economic situation. And, very interesting, attitudes tended to be influenced more by local situations rather than larger cultural factors.

Wiseman and Bogner (1997, 2003) have conducted several studies investigating environmental perspectives and ecological values of students. Among the findings of interest to the discussion they identified two attitudes, ‘Utilisation’ and ‘Preservation’ that were related in a causal fashion. That is, attitudes toward utilisation of the environment influence attitudes toward preservation of the environment.

A major Asia-Pacific study reports research on the attitudes, knowledge, and beliefs of 16-year-old students in 10 countries—Australia, Brunei, China, Fiji, India, Indonesia, Japan, New Zealand, Singapore, and Thailand (Yencken, Fien and Sykes, 2000). The study included a questionnaire completed by more than ten thousand students and focus group discussions held in a range of schools and classrooms in each participating country. The study found strong similarities in the findings across all countries. The level of awareness and understanding of 11 key concepts did vary throughout the region, but the overall pattern was very similar. For example, the concepts of ozone depletion and the enhanced greenhouse effect were well known in all countries. In contrast, understandings such as the precautionary principle and intergenerational equity were poorly expressed in all countries. Understanding sustainable development, biodiversity, and carrying capacity varied among the 16-year-olds in the 10 countries.

Of great importance to this chapter, the environmental belief systems of students were remarkably consistent. The investigators found that a majority of students expressed environmentally supportive views and beliefs. For example, a majority of students indicated that it was important to concentrate on protecting the environment even if it means reducing economic growth.

When it came to actions to help improve the environment the overall trends were again very similar. However, Japan stood out as a variation from these results. In most countries, apart from Japan, a majority of students stated that they have taken some deliberate pro-environmental actions such as recycling.

In summary, it seems clear that experiences at home, that is the role of the family and early experiences, have a significant influence on students’ attitudes toward the environment. These attitudes relate to college interests and study in courses more aligned with the environment. One should note that the cause and consequence of this finding is...
not clear. There are indications that students’ attitudes may be related to other beliefs and values that are broader than those narrowly associated with the environment. Some evidence indicates a positive effect on attitudes of placing science in an ethical context.

228. Summarising the actual attitudes held by students presents a situation where one can report that studies have identified students’ attitudes relative to the environment, but the terminology varies. It seems there is some consistency reporting students have ‘ecologist’ and ‘naturalistic’ attitudes to ‘follow nature’ and a causal relationship between ‘utilisation’ and ‘preservation.’ These studies suggest some consistency in students’ attitudes toward the environment. The students generally have attitudes that would be described as pro-environmental. In addition, there seems to be some general consistency among countries.

**Students’ Behaviours and the environment**

229. One assumption about scientific literacy, as this goal relates to the environment, is that higher levels of understanding and clearer values will result in pro-environmental behaviours. Pro-environmental behaviour includes behaviour that consciously seeks to minimise the negative effects of an individual’s, or a society’s, actions on the environment. For example, pro-environmental behaviour would include minimising resource and energy consumption, use of non-toxic substances, and active reduction of waste (Kollmuss and Agyeman, 2002).

230. Knowledge and awareness alone do not lead to pro-environmental behaviour. A person’s behaviour is influenced by his or her intentions, which are in turn influenced by attitudes and social pressures (Kollmus and Agyeman, 2002). For example, pro-environmental behaviour is more likely in individuals with a greater sense of personal responsibility (Hines, et al., 1986-1987). Direct experiences with the environment also have a stronger influence on people’s behaviour than indirect experiences (Kollmus and Agyeman, 2002).

231. Research indicates that childhood experience (Palmer and Suggate, 1996) and television viewing, in particular the news and nature documentaries (Holbert, Kwak and Shah, 2003), contribute to pro-environmental behaviours. An insightful finding emerges from a study of university students when the investigators found a high level of idealism and low level of commitment relative to environmental problems. This may be due to the abstract nature of environment and resource problems and the fact that many problems have little or no meaningful impact on students’ lives (Jurin and Fortner, 2002).

232. In summary, an individual’s pro-environmental behaviour likely is the result of multiple factors including knowledge, awareness, attitudes, and social pressure. The behaviour may result from direct experience with an environmental issue. Though media, such as television news and documentaries, may contribute. Experience, perhaps in school programmes, may help to reduce the contradictory situation of high idealism and low commitment to action relative to environmental problems.

**Science education and the environment**

233. Environmental education is a part of the science curriculum in many countries. Strategies for teaching about the environment vary. In Britain environmental education is taught as part of a cross-curricular theme. Students in the United States gain knowledge about the environment as part of the science curriculum or through more targeted environmental science courses, but they may also acquire knowledge through environmental education programmes that take place outside the classroom. In Uganda environmental education is incorporated into the science curriculum and is one of the core subjects at the primary level (Hale, 1993). Students also gain knowledge about environmental problems through personal experiences. However, a study in Poland (where most energy comes from coal-fired power plants which are the biggest source of air pollution) found that no students
mentioned having personal experience with energy. Malta has used a process of infusing small lessons on environmental topics into the curriculum (Ventura, 1993).

234. Some researchers have addressed issues about environmental education as an area of study or policy in school curricula. An international seminar held in the UK addressed the meanings of environmental education and education for sustainability (Barraza, Duque-Aristizabal and Rebolledo, 2003). For example, Fien and Heck (2003) summarised trends for a sustainable future in the Asia-Pacific region. Although the countries and organisations responded to the first phase of challenges to implement the sustainable development theme, there remains considerable work to move beyond ‘innovation without change.’ In short, innovative policies were in place without any evidence of change in educational practices, systems, or structures.

235. Paul Hart (2002) reported on the difficulties of including environmental education in the Canadian science curriculum. He argues that transforming the school science curriculum to incorporate environmental education requires reconceptualising science education in a morally open and political perspective. Likewise, attempts to promote environmental education in Scotland met negative administrative and political reactions (Lavery and Smyth, 2003). Munson (1997) reports on several barriers to ecology and sustainability education in the U.S. public schools. Additionally, a review of environmental education materials in the U.S. supported the ambiguous position of environmental education relative to school science programmes (Salmon, 2000).

236. In an editorial titled ‘Making Connections: Biology, Environmental Education and Sustainable Development,’ Slingsby and Barker (2003) report that environmental education has both a European identity and an international identity. This report stands as a counterpoint to Knapp’s (2000) view that environmental education is finding decreasing support in the international community. These alternative perspectives provide an opportunity to clarify issues of identity, support, and emphasis for environmental education within the international community.

237. Several studies on various goals of environmental education programmes reveal varied success in, for example, intergenerational influence (Ballantyne, Fien and Packer, 2000; Rovira, 2000), the role of education and experience in secondary students (Robinson and Kaleta, 1999), and future perspectives (Fleer, 2002).

238. Finally, the literature reports discussions and evaluations of practices such as the positive affects of outdoor activities in Finnish 11-12-year-olds, on students’ empathic relationship with nature, their social behaviour, and higher moral judgements (Palmberg and Kuru, 2000), the role of environmental education in use of ecological information in the solution of problems in developing countries such as Mexico (Castillo, Garcia-Ruvalcaba and Martinez, 2002), and use of discussion-based group work with 15-year-olds in England. This study reported the use and development of skill areas such as communication, numeracy, study, problem-solving, and cooperation (Gayford, 1993).

239. In summary, it seems that many countries have policies and provide educational opportunities for students to learn about the environment. This said, there is a tension concerning the emphasis on environmental issues and their location in school programmes. Are they part of science education or are they environmental education? An extension of this observation is the apparent contradiction in the identity and support for environmental education. There are reports on a variety of educational programmes and strategies that have positive effects on students’ knowledge, values, and behaviours vis a vis the environment and other important areas such as reading and mathematics.

POLICY RELEVANT ISSUES

240. At the level of the educational system as a whole and society, students’ knowledge, values, and actions relative to the environment are important as they ultimately affect the economy and the general health, welfare, and political and social actions of a nation. At
the level of educational institutions, it is important to know about the intended, actual, and learned outcomes relative to the environment. PISA will gather information beyond formal school settings. Clearly, educational institutions include schools, and they also include media, museums, and families. The student, school, and parental questionnaires afford the opportunity to gather valuable information in these domains. The questionnaires and assessment will provide aggregate information on individual participants in education and learning.

241. At a more specific level, a critical review of evidence addressing learners and learning in environmental education provides valuable insights for policy makers and assessment programmes such as PISA 2006. Relative to the environment, there are six concentrations or objects of study vis-à-vis learners and learning. Three concentrations are well established—students’ environmental knowledge, environmental attitudes and behaviours, and learning outcomes. Three objectives of studies are emerging. Those objectives are students’ perceptions of nature, experience of learning, and influences of adults (Rickinson, 2001). As seen in this brief review, the evidence base provides more information about students’ environmental knowledge and attitudes than about their educational experiences and preferences, and more about learning outcomes than about learning processes. Together with the PISA 2006 science assessment, the questionnaires present an opportunity to increase our understanding of students’ knowledge and attitudes, educational experiences and the influence of adults, relative to environmental issues.

242. The following policy relevant issues could be addressed by PISA 2006.

- What scientific knowledge do students demonstrate about environmental and resource issues? Associated with this question would be evidence of students’ misconception and confusion about such issues.
- What attitudes do students express relative to environmental and resource issues?

243. Obtain information that will answer these questions, and the international comparison, in itself, will be an important contribution for policy makers. In addition, PISA 2006 could provide data in response to questions such as:

- What are students’ perceptions of environmental issues? Do students perceive issues such as the use of energy, global warming, and pollution as problems? What problems do they perceive as most distressing?
- What are students’ learning experiences? This might include school, community, the home, and the media.
- What are the influences of adults on students’ knowledge, attitudes, and actions relative to environmental issues?
IMPLEMENTATION

244. Implementation of the recommendations from this discussion can be made through the student questionnaire, the parent questionnaire, the school questionnaire, and exercises and items in the student assessment.

245. Constraints of time and the need to represent a balance of contexts, content, and affective domains in the exercises and items within the assessment will constrain the implementation of the environment as a focus in PISA 2006. This said, there are ample options for the use of environment-related exercises. (See, e.g. the PISA 2006 Science Framework—Figure 2 on contexts, Figure 4 on knowledge, and Figure 6 on affective responses.)

246. Scales based on the questionnaires may help develop profiles of students’ knowledge and attitudes the environment in general and selected environmental issues in particular. For example, gender, pro-environmental attitudes, and types of school experiences may all be analysed.

247. Implementation of the environmental theme will result in cross-country data for analysis and subsequent external confirmation of extant information from other international assessments (Mullis et al., 2001) and validation of the themes discussed in this chapter.

248. Following extended discussions with the Questionnaire Expert Group, consultations with the Science Expert Group and National Project Managers, and review of the empirical outcomes of pilot and Field Trial data, the following constructs relating to the environment were recommended to the PISA Governing Board for inclusion in the PISA 2006 Main Survey questionnaires.

249. The following constructs were measured with item batteries included in the student questionnaire:

- Students' awareness of environmental issues
- Sources of information on environmental issues
- Students' perception of locus of impact of environmental issues
- Students' optimism/pessimism of environmental issues
- Students' attitude of responsibility for sustainable development

The following constructs were measured with item batteries included in the school questionnaire:

- Location of environmental issues in the curriculum
- School-based activities regarding the environment

In addition the following constructs were measured in the international option4 of a parent questionnaire:

- Parents' perception of impact of locus of impact of environmental issues
- Parents' optimism/pessimism on environmental issues

REFERENCES


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4 Countries may choose whether to administer the parent questionnaire. It is not a core component of the PISA study.


attitudes, activity levels, and knowledge concerning the environment. The Journal of

Ventura, F. (1993). Science and environmental education at the primary level in Malta: Separate

32(1): 77-108.


Wiseman, M. and Bogner, F. (1997). Environmental perspectives of Danish and Bavarian pupils:


ELABORATION

250. The organisation of education in a nation supplies the essential resources – e.g. funding, governance, and institutional structures – for the learning processes that produce student outcomes. There are two facts to keep in mind in order to appreciate the role of these macro-level factors in determining student outcomes such as those to be measured by PISA 2006.

251. First is the fact that the organisation of education is by and large a national phenomenon (e.g. Anderson-Levitt, 2003, LeTendre et al., 2001, Mills and Blossfeld 2003, Stevenson and Stigler, 1992). Over the 20th century the nation-state has emerged as the primary organiser, provider, and controller of schooling; consequently, the organisation of education is a product of a nation’s politics, history, economics, and culture. This creates differences among nations that make cross-national studies interesting and informative.

252. Second is the fact that although a nation creates and governs its own organisation of schooling, a pervasive worldwide culture of education generates considerable similarity among nations in the basics of education, particularly those aimed at the learning of universally agreed-upon subjects of science, mathematics, and language skills. As is true for many other public sectors of nations (e.g. health, social welfare, criminal justice), there are now significant similarities in the organisation of schools and educational policies around the world. This is particularly true among the many nations that have reached at least moderate economic development. A common world culture of education shapes similar values, norms, and even operating procedures in schools across all kinds of nations. The organisation of schooling has become more homogenous over time everywhere (e.g. Benavot et al.1991; Boli, Ramirez, and Meyer 1985; Fuller and Rubinson 1992).

253. Therefore, the variation in the organisation of education across nations is a result of a dynamic between two processes—one national and the other global (Baker and LeTendre, forthcoming 2005). It is too simplistic to say that schooling operates in the same way in all nations; this is not true. A truer image is one of a world culture of education providing the rules of the game for all nations, but in keeping to these basic rules nations play the game somewhat differently.

254. These contrasting forces of national differences and global similarities explain the well-documented paradox about macro-level factors and their effect on student outcomes: namely, cross-national variation in most macro factors does not vary much with cross-national variation in student achievement (e.g. Baker, Akiba, LeTendre, and Wiseman 2001; Boe et al. 2001; LeTendre, Akiba, Goesling, Wiseman, and Baker 2000). This is true even though formal schooling is perhaps the largest social intervention directed at children and youth ever undertaken in modern society. Public expenditures on schooling continue to rise and are among other large expenditures in most national budgets. And sending all children to long school careers has had considerable impact on human cognition (e.g. Blair et al. 2004, Martinez 2000). Hence the level of science, mathematics and language knowledge in all nations participating in PISA 2006 is largely attributable to the implementation of formal schooling. But if schooling is so essential to student outcomes in general, why is there a lack of cross-national effects of national styles of organisation of schools? There are two reasons.

255. First, as described above, the basics of education are similar across most nations. And it has been observed that world norms about operating schools tend over time to moderate any extreme national models of schooling, and this moderating effect has intensified over the past fifty years (Baker and LeTendre, 2005; Fuller and Rubinson 1992). Even though
the organisation of schooling is essential in the production of student achievement, there is generally less and less extreme cross-national variation in the ways to school students.

256. Second, macro factors about how education is organised in a nation are further away from the learning process than school and individual factors. Having a competent teacher or highly educated parents is more likely to influence a student’s achievement level than which nation he or she is schooled in. Students’ mastery of science, mathematics, and reading tends to differ the most from student to student, followed by less differences from school to school, to the least differences from nation to nation.

257. Macro organisational factors about schooling should be collected and analysed in PISA 2006 because of the essential role they play in producing student achievement. But they should be seen more as producing and distributing inputs to the learning process than as direct effects on student outcomes. For example, the organisation of schooling influences factors in a nation such as school and classroom size, teacher quality, curricular consistency, and instructional resources that are all known to have a direct effect on student outcomes. Further, cross-national comparisons of these factors assist national policy-makers in assessing the consequences of using different ways to organise schooling that may differ from emerging world norms.

POLICY ISSUES

258. Although most aspects of nations and their organisation of schooling do not associate directly with national achievement outcomes, two in particular do.

National Wealth

259. Usually measured as Gross Domestic Product (GDP) per population, national wealth has consistently been shown to be associated with average national achievement. Wealthier nations tend to have higher science and mathematics achievement than poorer nations (Baker 2002; Baker, Goesling, and LeTendre 2002; Heyneman and Loxley 1982, 1983). This occurs because of two related processes. First, wealthier nations have more families with wealth and higher parent education, both non-school factors that contribute to better student outcomes. Second, wealthier nations tend to spend large amounts of public funds on schooling and this has been shown to increase the quality of education and influence student outcomes (e.g. Hedges, Laine and Greenwald 1994). But in terms of pumping up the national average of achievement there are likely diminishing returns to investments after a high level of school quality has already been reached. Over time it has been observed that the relationship between national wealth and average levels of school achievement declines as the amount of educational investment in more nations yield high levels of school quality (Baker, Goesling, and LeTendre 2002). Also the rising and homogenising of school quality occurring within many nations explains why now effects of school characteristics on student outcomes are smaller compared to the effects of family background (Baker and LeTendre 2005; Schiller, Khmelkov and Wang. 2002).

Intended and/or unintended Resource Inequalities among Schools

260. Nations with higher degrees of inequalities in basic educational resources among schools have lower national averages in achievement (Baker, LeTendre and Goesling 2002). Furthermore, there is evidence that cross-national differences in social welfare policy aimed at alleviating the impact of family disadvantage on children are related to national levels of mathematics and science achievement among disadvantaged students (Thompson 2004; Baker 2002). Nations with higher social funding and effective administration of social welfare reduce the negative impact of family poverty and low parental education on achievement levels of students.
261. Besides these two factors, there are a number of aspects about the organisation of schooling in a nation that while not directly related to student achievement are related to how schools shape the learning process of students:

Centralisation/Decentralisation of School Governance

262. There has been much debate over the most effective level of governance for education decision-making to ensure the best student outcomes possible (e.g. Carnoy and Rhoten 2002). Historically, nations have tended to vary considerably on which level of government makes most operational decisions. Over the last several decades there has been a steady policy trend in many nations towards greater decentralisation, pushing more operational decisions down to the school and other local educational units. But at the same time there has been a fair amount of resistance toward full devolution, hence creating national education systems with considerable mixes of both centralised and decentralised decision-making occurring within the system. Further, although the degree to which the organisation of schooling is decentralised has been shown to decrease curricular consistency across schools and classrooms and other teaching factors, decentralisation has not been shown to directly influence national levels of student outcomes (Astiz et al. 2002, Desimone et al. forthcoming). Related to this governance factor are other factors like teachers’ and headmasters’ autonomy to make decisions about key schooling processes.

Comprehensive versus Specialised Secondary Schooling

263. The degree to which secondary schooling in nations is either comprehensive or streamed has traditionally been a major macro level difference among education systems. Although cross-national variation continues, over the past three decades there has been a distinct trend away from differentiation towards more comprehensive organisation in many nations. Comprehensive secondary schools offer the same leaving credential and attempt to provide similar curriculum and instruction to all students within one educational setting. Specialised secondary schooling comes in several forms; ranging from the organisationally weak, locally-determined curricular tracking found in some American secondary schools to the completely separate schools with unique leaving credentials and curricular and instructional experiences found in German secondary education. Although differentiation of schooling within nations tends to be a persistent factor influencing differences in school outcomes, there is little evidence to suggest that streamed national systems perform better or worse than comprehensive ones, except for when differentiation leads to large quality differences among schools as discussed above. But this factor of the organisation of education can greatly influence more proximal conditions that shape learning, such as access to different levels of the science or mathematics curricula, make-up of classrooms in terms of levels of prior knowledge, educational and career aspirations of students and their parents, and so on. Furthermore, it has been shown that streaming in some national systems can enhance the influence of the family’s social background on student achievement (Baumert and Schümer 2001).

Examination Regime/ School Selection Process

264. As over the past several decades a number of East Asian nations have consistently scored high on international science and mathematics assessments, much attention has been given to the idea that high-stakes tests for future education might relate to national differences in achievement. The idea is that students’ motivation to learn heightens in preparation for a high-stakes test, as are often used in East Asian education systems. While there is some evidence that the presence of such test regimes in national systems is associated with national achievement (Bishop 1998), another study finds that the association is weak and perhaps non-existent (Baker, Akiba, LeTendre, and Wiseman 2001). Nevertheless, how students are allocated to different schools, particularly in the secondary sector, shapes the
socialisation process by which education motivations and expectations are developed among students, and this has been shown to vary cross-nationally (Buchmann and Dalton 2002).

**Funding and Distribution of Resources**

265. The level of funding of education has been shown to influence school quality that in turn influences the level of student outcomes. Further, as described above, there is evidence of cross-national effects of wealth on achievement (Baker, Goesling, and LeTendre 2002, Heyneman and Loxley 1983). How funds are distributed throughout the education system is also a key factor of the organisation of schooling in a nation.

**Educational Credentials and Links to Higher Education and Labour Market**

266. Similar to the factor of school differentiation is the degree to which secondary educational credentials are linked to tertiary education and/or the labour market. Nations vary by the degree to which there are tight or loose links. For example, in some nations secondary credentials are entitlements to study at the universities, while in others there is only a weak connection. In some nations grades on achievement are taken into account in the hiring process more than others. Also, like with examination regimes, this factor has been shown to influence motivation to learn and aspirations for future education (Buchmann and Dalton 2002). Finally, the worldwide trend across economically developed nations to expand tertiary education is probably the most dynamic educational change presently occurring in many nations today. Understanding cross-national variation in how secondary education articulates with the higher education sector will increasingly become a central issue for policy about the academic preparation and motivation of students for advanced scientific and technical training in tertiary institutions.

**Relationship of Formal Education to Shadow Education System**

267. The use of outside formal school tutoring, exam preparation and many other forms of private assistance for the student’s achievement in subjects like science, mathematics and reading in school has become a worldwide phenomenon of major proportions (Bray 1999). The amount of this shadow education varies extensively across nations, and although this variation is not related to cross-national achievement, it is rapidly becoming a dynamic feature of education (Baker, Akiba, LeTendre and Wiseman 2001). It has also been shown that the presence of extensive shadow education has influences on the basic instructional patterns in formal schooling in mathematics and science that can in turn influence achievement (LeTendre 1994; OERI 1998). Lastly, shadow education is part of a larger process whereby private resources of families and even new private businesses providing education services are influencing how education is organised in many nations (Aurini and Davies 2004).

**Privatisation**

268. The degree of privatisation of primary and secondary education is a salient feature of national education systems. In some nations, such as the U.S. and Chile, there is research showing some differential effects of private and public schooling on achievement. But as an international topic, there is no research on whether or not a nation’s mixture of private and public schooling has an impact on student outcomes (see Dronkers and Robert 2004 for an emerging exception).

**Performance Accountability of School Management**

269. Along with the global trend towards more decentralisation in national education systems, there is growing use of performance accountability provided by schools to assess educational productivity. In some nations, aggregate growth levels of student
achievement in core subjects like science, mathematics and reading are now used to evaluate school management and even teacher effectiveness. At the same time, many other nations do not use this managerial approach. As this is a relatively new feature in the nations using it, there are no cross-national analyses of any potential influences of this factor on student outcomes or on other proximal factors to learning. But given the various assumptions of greater educational productivity underlying the launching of these new accountability policies, it will be useful to collect cross-national information on it in PISA 2006.

IMPLEMENTATION

270. Factors about the organisation of education in a nation vary as to how they can be collected. There are three different kinds of factors which will be described in this section:

a) National Factors that can be collected for the nation as a whole from official documents, experts, or from other cross-national data

b) National Factors that can be collected from aggregating individual responses of respondents at the school and/or student level

c) Placing sampled schools into the overall organisation of education within the nation

National Factors that can be collected for the nation as a whole from official documents, experts, or from other cross-national data

271. Included among these are factors that are outside the educational system such the nation’s GDP, demographic structure, and so forth. Additionally, there are factors about the national system of education that can be collected from summary judgements of national experts, official documentation, or from the data products of other cross-national studies such OECD’s Education at a Glance series. The latter offers the advantage of the prior considerable definitional work to make indicators as comparable as possible across nations that come at no cost to a new study.

272. These measures are easy to incorporate into PISA, but there are two challenges to accurate collection. First, it has been shown from the experiences of past cross-national studies of school achievement that sometimes national expert summary judgements and even official documentation miss important emerging national trends that are better observed with aggregated information from school personnel (e.g. Astiz et al. 2002). Second, summary national measures from a single source are less accurate in nations where there is more regional or local variation in operating procedures, therefore some indicators of national factors should be collected at the school level where aggregations and distributions can be assessed.

273. While future analysts of the PISA 2006 data can collect many such national factors on their own after the study at almost no cost, having many of these factors centrally collected and added to the PISA 2006 analysis files would facilitate more use of these kinds of information in secondary analyses of the school and student assessment data.

274. Operating and organisational factors described above that can be collected this way are:

- **National Wealth**, (e.g. gross domestic product per population, and other national economic factors such as income inequality measures)
- **Funding and Distribution of Resources**, (e.g. percentage of GDP spent on secondary education, average per pupil expenditure in constant currency; official policy about the distribution of resources among schools)
- **National Demographics**, (e.g. size of population, age structure; these will needed as controls in analyses of other national factors)
• **Privatisation.** (e.g. percent of schools and/or enrolments in public and private sectors, types of private schools)

• **Comprehensive versus Specialised Secondary Schooling.** (e.g. use of school streams, within-school tracks, leaving credentials)

• **Educational Credentials and Links to Higher Education and Labour Market.** (e.g. judgement of the ‘tightness’ of the link between secondary school performance and future education and labour market opportunities)

• **Examination Regime/ School Selection Process.** (e.g. occurrence of national or common examinations, the level of the stakes for performance, and timing in the schooling process; see Bishop 1998 for a workable coding scheme)

*National Factors that can be collected from aggregating individual responses of respondents at the school and/or student level*

275. Included among these factors are ones that are more difficult to measure for the nation as a whole from just one source, usually because there is change occurring in some aspect of school governance in nations, such as decentralisation of decision-making. Furthermore, measuring national factors from aggregated responses at a lower level in the system allow for characteristics of a distribution to be used as variables. For example, this procedure can be very useful in estimating the degree to which the system of education in a nation produces resources inequalities across schools, which can then be summarised for each nation by standard measures of distributional inequality (Baker, LeTendre and Goesling 2002). Lastly, for some of the factors that can be measured from a single source, additional indicators from aggregation provide variables that capture other dimensions of the factor.

276. The costs of including these kinds of measures are higher than the ones described in type 1 above because they require items in the school and/or student questionnaires. But for some national factors of school organisation the costs are justified in terms of accuracy and availability of suitable information.

277. Operating and organisational factors described above that can be collected this way are:

- **Intended and/or unintended Resource Inequalities among Schools.** (e.g. aggregation and between-school inequality measures of headmasters’ estimation of resource quality for instructional purposes; there are numerous examples of items on specific resources in past IEA questionnaires that have proved useful in estimating this factor)

- **Relationship of Formal Education to Shadow Education System.** (e.g. a set of items for the student to answer that measure his or her use of shadow education on a weekly base for science, mathematics, and/or reading; TIMSS-95 has an item set that would also be useful to estimate national factors, as well as useful in student-level analyses)

- **Centralisation/Decentralisation of School Governance.** (e.g. aggregation of responses from headmasters’ judgement of different levels of government influence on operational decision-making; PISA currently has a set of items on this)

- **Performance Accountability of School Management.** (e.g. headmaster’s response on use of any such processes in his or teachers’ evaluations; this could be done only for nations where there is some use of these new management techniques)

*Placing sampled schools into the overall organisation of education within the nation*

278. One of the challenges in using information about the national organisation of education in analyses of school and student data is the need to have accurate assessment of where the
sampled school resides in the overall system of schools. While individual national research centres for PISA can do this for their own national sample, these are not available cross-nationally for comparative analysis purposes. This has never been done before in an international study of achievement and would represent a considerable innovation in PISA 2006.

279. One way to do this would be for national experts to develop a matrix of salient national characteristics of secondary schools where 15 year-olds study. Formal characteristics thought to be related to student outcomes should be given priority. For example, in Germany this would be the three types of streamed schools and perhaps several others types. In other national systems it would be other characteristics. The headmaster of each sampled school would be asked to place the school on the national matrix of relevant characteristics. These would be coded into the data with accompanying technical explanation to help international researchers understand the chosen characteristics in each national system.

Proposed Implementation in Questionnaire Material

280. Following extended discussions with the Questionnaire Expert Group, consultations with the Science Expert Group and National Project Managers, and review of the empirical outcomes of pilot and Field Trial data, the following constructs relating to the environment were recommended to the PISA Governing Board for inclusion in the PISA 2006 Main Survey questionnaires.

281. The following construct was measured in the student questionnaire:

- Time spent in out of school lessons

282. The following constructs were measured with items or item batteries included in the school questionnaire:

- School management (private/public)
- Source of school funding
- School organisational characteristics (grades, programmes, grade repetition, class size)
- Occurrence of ability grouping
- Instructional resources
- Centralisation/decentralisation of school governance
- Performance accountability of school management
- Admittance policies and parental choice

283. In addition the following constructs were measured in the international option of a parent questionnaire:

- Parents' perception of the value and quality of schooling
- The cost of educational services

REFERENCES


