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**PREDICTORS OF ATTITUDES AND KNOWLEDGE OF STUDENTS IN PISA
2006: A COMPARISON BETWEEN DIFFERENT CULTURAL CONTEXTS**

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**Predictors of Attitudes and Knowledge of Students in PISA 2006:
A Comparison between different cultural contexts**

**[Preditores das Atitudes e do Conhecimento dos Estudantes no
PISA 2006: Comparação Entre Diferentes Contextos Culturais]**

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ABSTRACT

This study examines the relative influence of students' characteristics, family background, school characteristics and cultural context in the attitudes and knowledge about science in Europe and Asia, using the OECD's 2006 Programme for International Student Assessment (PISA). We use data from two European and two Asian countries that differ regarding their level of PISA results: "high-achievers" (Belgium N = 8,857 and Korea N = 5,176) and "low-achievers" (Portugal N = 5,109 and Thailand N = 6,192). Results show variations in the sets of predictors that explain the differences of attitudes and knowledge of 15-year-old students about science. The set of predictors of students' science knowledge explains a high degree of variance, but the degree in European countries (Portugal = 63.0%, Belgium = 54.2%) is higher than in Asian countries (Thailand = 40.3%, Korea = 39.6%). In European countries, student characteristics play a very important role in explaining differences in knowledge (Portugal = 48.3%, Belgium = 28.5%); in Asian countries, the percentage of variance explained by these variables is less relevant (Thailand = 14.8%, Korea = 0.8%). However, in both regions, gender, grade and age are more significant in countries where the level of knowledge is lower. In Asian countries, family background is the strongest predicting variable.

The set of predictors of students' science attitudes explains a similar degree of variance for both European and Asian countries (Portugal = 22.9%,

Belgium = 20.6%, Thailand = 22.5% and Korea = 26.0%). Individual level variables (science self-efficacy) are the most influential in scientific attitudes. Science self-efficacy is, across cultures and domains, the most significant and important predictor for both scientific knowledge and attitudes.

Keywords: student attitudes, student knowledge, cross-cultural differences, scientific literacy, secondary analysis

RESUMO

Este estudo examina a influência relativa das características dos estudantes, do contexto familiar, das características da escola e do contexto cultural nas atitudes e no conhecimento sobre ciência na Europa e na Ásia, recorrendo ao Programa Internacional de Avaliação de Alunos (PISA) 2006 da OCDE. Usamos dados de dois países europeus e dois países asiáticos que diferem quanto ao nível de resultados do PISA: “elevados desempenhos” (Bélgica N = 8.857 e Coreia N = 5.176) e “baixos desempenhos” (Portugal N = 5.109 e Tailândia N = 6.192). Os resultados mostram variações nos conjuntos de preditores que explicam as diferenças nas atitudes e no conhecimento dos alunos de 15 anos sobre ciência. O conjunto de preditores dos conhecimentos de ciência explica um elevado grau de variância, mas superior nos países europeus (Portugal = 63.0%, Bélgica = 54.2%) do que nos países asiáticos (Tailândia = 40.3%, Coreia = 39.6%). Nos países europeus, as características dos alunos desempenham um papel importante na explicação das diferenças no conhecimento (Portugal = 48.3%, Bélgica = 28.5%); nos países asiáticos, a percentagem de variância explicada por estas variáveis é menos relevante (Tailândia = 14.8%, Coreia = 0.8%). Contudo, em ambas as regiões, o género, o ano de escolaridade e a idade são mais significativos em países onde o nível de conhecimento é mais baixo. Nos países asiáticos, o ambiente familiar é a mais forte variável preditiva.

O conjunto de preditores das atitudes dos estudantes face às ciências explica um grau semelhante de variação para países europeus e asiáticos (Portugal = 22.9%, Bélgica = 20.6%, Tailândia = 22.5% e Coreia = 26.0%). Variáveis de nível individual (auto-eficácia em ciência) são as mais influentes nas atitudes científicas. A auto-eficácia em ciência é, aliás, o preditor que, através de domínios e culturas, é relevante e significativo tanto para o conhecimento como para as atitudes científicas.

Palavras-chave: atitudes dos alunos, conhecimento dos alunos, diferenças interculturais, literacia científica, análise secundária

RÉSUMÉ

Cette étude examine l'influence relative des caractéristiques des élèves, de contexte familial, des caractéristiques de l'école et le contexte culturel dans les attitudes et les connaissances en sciences en Europe et en Asie, en utilisant le Programme International pour le Suivi des Acquis des Élèves 2006 (PISA) de l'OCDE. Nous utilisons les données de deux pays européennes et deux pays asiatiques qui diffèrent quant à leur niveau de résultats du PISA: "haut performantes" (Belgique N = 8,857 et Corée N = 5,176) et les "bas performantes" (Portugal N = 5,109 et Thaïlande N = 6,192). Les résultats montrent des variations dans les ensembles de prédicteurs qui expliquent les différences d'attitudes et de connaissances des élèves de 15 ans en science. L'ensemble des prédicteurs de la connaissance des élèves en science explique un haut degré de variance, plus élevé dans les pays européens (Portugal = 63,0%, Belgique = 54,2%) que dans les pays asiatiques (Thaïlande = 40,3%, Corée = 39,6%). Dans les pays européens, les caractéristiques des élèves jouent un rôle très important dans l'explication des différences dans la connaissance (Portugal = 48,3%, Belgique = 28,5%); dans les pays asiatiques, le pourcentage de variance expliquée par ces variables est moins pertinent (Thaïlande = 14,8%, Corée = 0,8%). Toutefois, dans les deux régions, le genre, le grade et l'âge sont plus importantes dans les pays où le niveau de connaissance est plus faible. Dans les pays asiatiques, le contexte familial est la variable prédictive la plus puissante.

L'ensemble de prédicteurs des attitudes des élèves en sciences, explique un similaire degré de variation pour les pays européens et asiatiques (Portugal = 22.9%, Belgique = 20.6%, Thaïlande = 22.5% et Corée = 26.0%). Les variables au niveau individuel (auto-efficacité en science) sont les plus influents dans les attitudes scientifiques. L'auto-efficacité en science est le prédicteur le plus significatif et important, au travers des cultures et domaines, pour la connaissance et les attitudes scientifiques.

Mots clés: attitudes des élèves, connaissances des élèves, différences interculturelles, culture scientifique, analyse secondaire

DEDICATION OF THE THESIS

This doctoral dissertation is dedicated to my parents and all family members for their endless love, support and encouragement. It also crucial this work should be dedicated to my beloved boyfriend, who has been always by my side, no matter how far the distance he is, how long that the destiny parting us from each other, he has always been my heart and soul . For 5 years, we have been being away from each other but his true love and care never change and that is the tremendous support for my accomplishment.

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LIST OF ABBREVIATIONS

AMOS	AMOS Program
CFI	Comparative Fit Index
CMIN/DF	Chi square/Degree of Freedom ratio
C.I.	Centrality Index
df	Degrees of freedom
EPS	Explain Phenomena Scientifically
e.g.	<i>Exempli gratia</i> , for example
et al.	<i>Et alii</i> , and other
ISI	Identifying Scientific Issues
ISCED	International Standard Classification of Education
ISCED 1	Primary education
ISCED 2	Lower secondary education
ISCED 3B, C	Vocational/ Pre-Vocational Upper secondary education
ISCED 3A	Upper secondary education
ISCED 4	Post-secondary non-tertiary education
ISCED 5B	Vocational tertiary education
ISCED 5A,6	Theoretically oriented tertiary and Post-graduate
MANOVA	Multivariate analysis of variance
N	Sample size
OECD	Organization for Economic Cooperation and Development

LIST OF ABBREVIATIONS (Cont.)

PISA	Programme for International Student Assessment
P-value	Probability of obtaining a test statistic at the significant level 0.05, 0.01, and 0.001
RMSEA	Root Mean Square Error of Approximation
USE	Using Scientific Evidence
Z	Standard Score (Z-score)
χ^2	Chi – square Statistics

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INTRODUCTION

In the last decades, large-scale comparative studies in education have become increasingly popular and at the forefront of public discussion regarding education and its effectiveness across countries. Even if this discussion is partly based on deceptive assumptions, like that is it possible to construct reliable tests that can be used across countries and cultures to assess students' literacy and that the results of these tests can be reliably associated with specific pedagogic practices than can, thereafter, be imported or exported across countries and cultures (Rochex, 2006; Steiner-Khamsi, 2004). However, these large-scale studies have undoubtedly changed the face of educational research and provide researchers with rich and extensive cross-national databases that can be used for other purposes, including a consideration of smaller samples of countries that allow a deeper attention to the social and cultural context of the research (Zhao et al., 2008) – a frequent limitation of large-scale studies.

In the context of this thesis, the initial goal was to explore PISA 2006 with a small sample of two countries, Portugal and Thailand – but the results inspired us to go further and also include two more countries, Belgium and Korea, thus contrasting European and Asian countries who have different profiles in terms of students' achievement: below (Portugal and Thailand) and above (Belgium and Korea) the international mean for scientific literacy. Therefore, we try to confront some of the limitations of large-scale research exploring the specificities of each

cultural and national context, intertwined with issues of system's effectiveness. More specifically, the goal is to explore how variables such as individual characteristics, family background, school learning and scientific interest and self-efficacy predict attitudes and knowledge of students about science, and how these predictors vary as a function of cultural context and national OECD average.

In contemporary societies, science is relevant to everyone's life, and the academic and public discourse about the relevance of scientific knowledge as an important part of people's lives has increased enormously. Not surprisingly PISA included scientific literacy in the student assessment because it emphasized the importance of science in normal daily lives rather than science subject taught in school (OECD 2006, p. 20). PISA 2006 aimed to assess the cognitive and affective aspects of scientific literacy. However, what scientific knowledge is (or should be) also changed. Lee (1999) defined the conceptual changing in science education research as "consistently define scientific knowledge in terms of concepts, principles, theories, and models that are important for all students to know, understand, and use in the fields or disciplines of science" (p. 189). The argument is that some general scientific and technological literacy is essential for effective participation in the twenty-first century in work and beyond and that that literacy requires a certain variety of scientific knowledge (Lee & Fradd, 1996). These assumptions guided educational reform agendas that started aiming a general scientific literacy, even if some academics oppose to this vision of a general scientific literacy, considering that science implies specific cognitive competences

(Levitt, 1999). However, the appealing vision of scientific literacy, as the knowledge of substantive scientific content that is essential for an understanding of human activity and the world, as defined by Mayer (1997), seems to be growingly more influential as science appears to become recognized as relevant to everyone's life, and an understanding of science and technology emerge as an essential tool for people to achieve their goals and participate in modern society (AAAS, 1989; Lee & Fradd, 1996; OECD, 2006).

Science literacy has a relatively long history and an extensive use in science education, more or less since the inclusion of science in the school curriculum during the 19th century, in Europe, U.S. and Asia (DeBoer, 2000). Various experts in science education have proposed definitions of the concept (e.g., Bybee, 1997; DeBoer, 2000; Fensham, 2000; Koballa et al., 1997; Mayer & Kumano, 2002). However, Osborne (2007) considers that contemporary science curricula and practices are primarily “foundationalist”, that is, the curricula tend to favour educating future scientists *over* educating future citizens. Roberts (2007) revises these two opposing traditions by asking: Should the curriculum emphasize scientific contents as such or should it link to life situations that depend on a scientific perspective? Obviously the former assumes “future scientists” as the target group, while the latter aims “future citizens”.

However, whether the goal is to promote high levels of scientific knowledge or the capacity to apply scientific knowledge there is a tendency for not recognizing the role of interests, attitudes, beliefs, and values, only to mention

intra-individual variables whose relevance has been proved (Bybee & McCrae, 2011). Even if research has explored the role of attitudes and interests (Alsop & Watts, 2003; Koballa & Glynn, 2007; Osborne et al., 2003), it is important to further our knowledge regarding their influence on scientific literacy. In fact, attitudes and interests established in early childhood play an important role on lifelong scientific literacy (Schroeder et al., 2009); empirical studies show positive and significant relationships between formal scientific knowledge and attitudes toward science (Sturgis & Allum, 2004; Bybee, 2008). Moreover, contextual variables can play an important role, both in scientific knowledge and interest. Research has found no significant differences between females and males in science performance and capability (Marks, 2008); but scientific interest is strongly related to family background, particularly parental education, family income, and outcomes; additionally, parental education and family income are positively correlated with the probability that young people continue to study after secondary education (Sandefur et al., 2005; Settersten et al., 2005).

In previous research, the determinants of schooling quality across countries were studied using cross-cultural regression (Barro & Lee, 2001). The studies explored the role of variables such as resources allocated to education (e.g. teachers per pupil or expenditures per student) and other factors such as parents' income or instructional level – and, interestingly enough, Barro and Lee (2001) found these factors (the level of school resources, such as pupil-teacher ratios,

family income and education of parents) were positively correlated with student performance.

We hope that this study will contribute to a broader understanding of the dynamic interplay between educational and cultural variables in cross-cultural research that will allow for a reflexive and critical discussion of international comparisons of educational achievement.

As we said above, the main objective of this study is to investigate and compare the predictors of attitudes and knowledge of students in PISA 2006 between two European and two Asian countries. The research questions include:

1. What are the predictors of students' attitudes and knowledge in PISA 2006?
2. Are there differences between the predictors of attitudes and knowledge between European and Asian students?
3. Does the country's diverse profile in terms of PISA results, moderate the influence of the predictors?

The thesis is constructed with five main chapters. Chapter I presents the meanings and debates surrounding comparative education. Comparative perspectives in education are presented. Meaning and dimension of comparative education are defined. Also, at the end of the chapter, some examples of comparative education studies using PISA are shown.

The second chapter focuses primarily on the review of scientific literacy. Starting by exploring the history and evolution of scientific literacy, then the debates and controversies of scientific literacy will be introduced. The importance of scientific literacy will be emphasized, and at the end of the chapter we present the understanding of scientific literacy from PISA's perspective.

Chapter III will provide details of research questions, research instruments, population and sample, data collection and data analysis. At the end of the chapter we present some general information regarding each country's education system. The sample countries were selected from two continents. European countries are Belgium, Portugal, and Asian countries are Korea and Thailand. Descriptive statistics were analyzed regarding gender, grade, educational level of parents and the amount of books at home.

Finally, chapter IV will present the findings of the study, starting with a descriptive statistics analysis for each country. Multivariate analysis of variance (MANOVA) is used to analyze group differences and study the relationship between variables. Then, the multiple regression analysis is conducted in order to find the most relevant predictors of science knowledge and attitudes for each of the selected countries. The last section of the chapter will present the results of a multiple group analysis performed to examine the invariance of predictors of science knowledge and attitudes. As we predicted, there are significant and relevant cross-cultural and cross-country variations.

In the conclusion we will discuss the most important results, implications and the limitation of the study. Lastly, recommendations are also provided for the future research.

CHAPTER I

COMPARATIVE EDUCATION: MEANINGS AND DEBATES

Comparative education involves the study and analysis of education systems, policies, goals, processes or results ... in various countries, taking into account the influence of social, cultural, economic, and political factors (e.g., Anderson, 1961; Daele, 1993; Joubish, 2009; Noah and Eckstein, 1969; Potts, 2007; Wilson, 2003). A traditional sub-discipline of education sciences, comparative education is viewed as present in historical records, as early as Herodotus (484-425 BC), that describe characteristics of educational systems, references to the management of education or to educational philosophy in various countries (Brickman, 1966; Epstein, 2008). However, comparative education was more formally instituted in the early nineteen century through the use of a scientific approach to education with a comparative perspective by Basset (1808) and Jullien (1817), among other influential European and north-American authors (see Brickman, 2010, for a review). But during the last century the discipline received a definitive impulse with the establishment of the International Bureau of Education (IBE) as a UNESCO center in 1948, the creation of the Comparative and International Education Society (CIES) in 1956, and the development of international comparative studies, first by the International Association for the Evaluation of Educational Achievement (*IEA*) and more recently by the OECD. In fact, the IBE developed an archive on educational systems of affiliated countries or

member states around the world that became the World Data on Education (WDE), including annual national reports on educational development that constitute a rich basis for the comparison of educational data among nations. Additionally, the creation of the IEA, in 1958, generated an interest for comparative cross-national studies on educational assessment and provided broad databases of representative samples of students from different educational levels on different domains such as science and mathematics, computer and information literacy, maternal language or civic knowledge and competencies. In the last decade, the OECD started a program that aims to provide member states with an index of educational quality relevant for economic development, considering three domains (reading, mathematics and science) and focusing on national representative samples of pupils at age 15. These international research projects engendered an intensive engagement of countries across the world and the ranking of countries based on the results obtained became an extremely popular phenomena in itself (Schleicher, 2007; Carvalho, 2009; Kim et al., 2009) – and therefore comparative education plays a central role in education sciences today, both regarding research and the ‘public image’ of the discipline.

This chapter intends to summarize the features and debates surrounding comparative education, focusing mainly on the comparative perspectives in education, exploring the meanings and dimensions of comparative education, the categorizing of comparative education research, and the theoretical approaches underlying comparative education.

1. Comparative perspectives in education

Educational contexts across the globe have changed rapidly, and education is increasingly seen as a decisive factor for a country's social and economic development, that appears increasingly to depend on higher levels of education and more specialized training (OECD, 2006). Some authors even argue that the countries that are currently in the process of education reform demonstrate improvements in areas such as natural preservation, social development, and economic growth (Metzger et al., 2010). At the present time, therefore, education plays a recognized central role in human development (Krueger & Lindahl, 2001) and it is also an important source of human capital development and economic growth (De la Fuente & Ciccone, 2002). It is therefore not surprising that Hanushek and Kimko (2000) and Barro (2001) propose that the quality of education as measured by international comparison test of skills has a strong relationship with economic growth.

Broadfoot (2000) affirmed that, eventually, comparative education is about the reform of the educational system in each country as comparative education examines features of the educational systems to confirm what is the most effective and then used this understanding to impact education policies and practices. This vision is classic in comparative education: Kandel (1933) stated that its objective was to discover the differences in the forces and causes that give rise to differences in the education systems, while Hans (1949) asserted that its purpose was to discover the underlying principles governing the development of all national

systems of education. However, there is clearly some debate whether this comparison has descriptive or normative goals (Garcia Garrido, 1987; Steiner-Khamsi, 2004). But there is no doubt that globalization has influenced comparative education (Carnoy, 2006; Steiner-Khamsi, 2004).

In general, the field of comparative and international education has emphasized three principal interrelated goals: 1) the development of theory, that could be named an academic or scientific view; 2) the improvement of practice and policy, that could be named a pragmatic view, and 3) to understand processes and mechanisms of international/ global education, that could be named a comprehensive view (Arnove, 2007).

In some cases, the main goal of comparative education has been to contribute to theory building, establishing relationships between variables operating in school systems (Farrell, 1979). This means, as Bray and Thomas (1995) noted, that researchers can look at the entire world as a natural laboratory to view the multiple ways in which societal factors, educational policies, and practices may vary and interact in otherwise uncertain and impossible ways. It was this type of research that allowed considering the relative influence of school-related variables or socio-economic background in determining student achievement; cross-national data showed that the social class, social status and economic inequalities are more important in determining access to higher levels of the education system and better jobs (Heyneman, 1979; Riddell, 1997).

Other studies use a pragmatist view, assuming that the reason for studying different education systems is to discover what can be learned to improve educational policy and practice. Altbach (1998) has discussed the process involved in the transfer of research and practice in education between the lending and borrowing – even if the most important principle to be derived from the study of the history of education lending and borrowing is that no system is the best system, as all have strengths as well as weaknesses.

The third goal has become an increasingly important feature of comparative education as the process of globalization became more central in contemporary societies – and while international education emphasized descriptive accounts of discrete countries and regions of the world (Alger & Harf, 1986), global education considers values, transactions, actors, mechanisms, procedures, and issues (Arnove, 2007).

Based on a classical study of comparative education across the world, Halls (1990) proposed a typology of comparative education that recognizes a diversity of sub-areas (see Figure 1). In his view, there are four major fields of comparative education: comparative studies, education abroad, international education and development education. Comparative studies can be subdivided into:

- i) *comparative pedagogy*, the study of teaching and classroom processes in different countries, recognizing that pedagogy is a complex field of practice, theory and research, that is undoubtedly; challenged when

combining the study of education in different countries with the study of teaching and learning,

- ii) *intra-education and intra-cultural analysis*, that involves the study of the various levels of education, and also

“systematically researches the historical, social, cultural, political, religious, economic and philosophical forces that partly determine and are partly determined by the character of education systems, and compares the resultant outcomes in two or more systems, areas or even globally” (Halls, 1990, p. 24).

The study of aspects of an educational system or systems in a country other than one's own, including studies about the educational system or policies constitutes what Halls (1990) designates as *education abroad*.

Additionally, *international education* includes:

- i) *international pedagogy* with a focus on cultural diversity, multiculturalism and “the education of linguistic or ethnic minorities”, but also the concern for issues such as “education for international understanding, peace education, and international population and ecological studies” (p. 24); and

- ii) *the study of the work of international education institutions* with a focus on policies, namely international agreements regarding qualifications, such as the Bologna declaration.

Finally, Halls (1990) refers to *development education* as a field of practice and research that is concerned with the development of guidelines that might assist policymakers and support the implementation of educational methods or training programs.

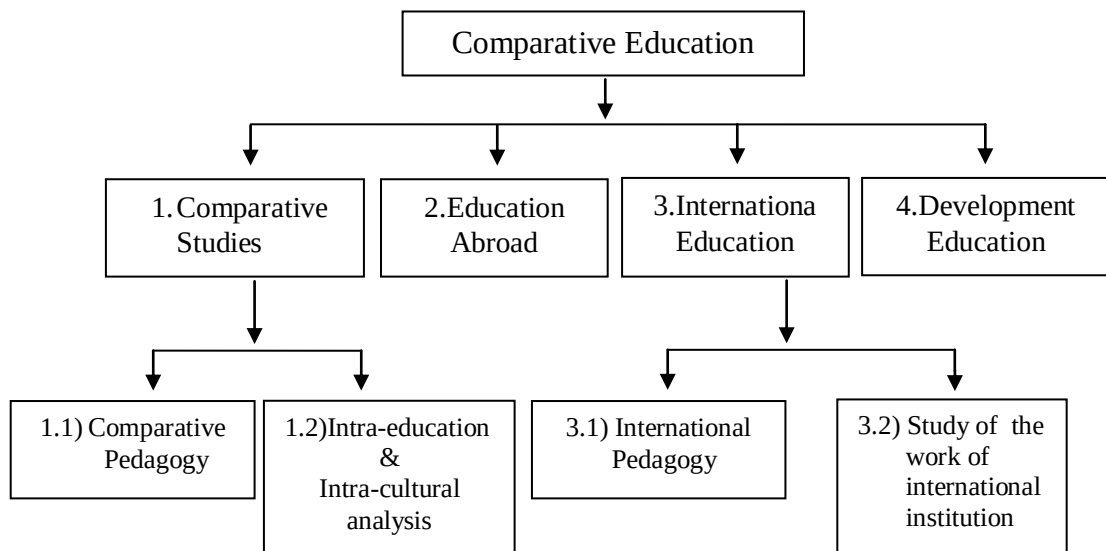


Figure 1. Model of Comparative Education (Halls, 1990, p. 23)

2. Foundations and definitions of comparative education

On the whole, it is clear that comparative education is strongly dominated by cross-national perspectives and most textbooks reflect the importance of this (Altbach et al., 1982; Bray & Yamato, 2003; Kim, 2003; Wilson, 2003; Schulte, 2003; Trahar, 2006; Arnoe & Torres, 2007; Metzger et al., 2010; Thieme et al., 2011), leaving Rust (2001) to state that most comparative educators “would likely feel comfortable with the notion that comparative education deals mainly with the analysis of educational systems and problems in two or more national contexts” (p.iii). Education systems in different countries are an obvious source of analysis in several studies of comparative education (Postlethwaite, 1988; Le Métails, 2001). However, since the establishment of the discipline, emphasis on “cross-national quantitative research” coexists with the call for “single-case, historical studies” (Silova, 2009, p. 17).

Nevertheless, even if comparison is inherently present in educational phenomena – as mainly all educational actors systematically use or are confronted with some kind of comparison mechanism in their daily experience of education –, the comparison between educational goals, policies, systems ... across-countries or historical periods poses specific challenges related to the homogeneity or diversity of the experiences under comparison (Endo, 2003; Metzger et al., 2010; Thieme et al., 2011; Kim & Nehm, 2011). For instance, McLaughlin (2004) reflects on some of the problems involved:

“ ‘comparison’ invites attention to: (a) *what is being compared with what* (e.g. teachers, schools, teaching methods and educational systems in differing cultural, national and regional contexts); (b) *the evaluative basis of comparison* (e.g. the norms and principles being invoked in making comparisons); (c) *the reasons and motives underlying the comparisons being made* (e.g. disinterested scholarly enquiry, a search for insights, etc., to be applied from one context to another); (d) *the methods used in making comparisons* (e.g. methods based on natural science, social science, hermeneutic traditions, etc.)” (p. 475).

Paulston (2000) also underlined how different “representations of the rhetorical, spatial and pictorial imaginations” (p. 363) have influenced the cultural landscape in which comparative education is located, and urged researchers “to question how our choice of ideas and forms of representation influence our views of how reality is constituted and construed, also how meaning and value are created and imposed on an otherwise unruly world” (p. 264). In fact, as Gita Steiner-Khamsi (2004) states “there is [now] a global trend of transnational borrowing and lending in education” (p. 1) but researchers should be critical of normative visions – that comparative education aims to export/ import ‘effective models’ from one country to the other – and try to understand

“how and why educational reforms are transplanted from one context to the another, whether borrowing is wholesale or by design selective (...), how decision makers justify reforms to an informed and interested public

(...) [recognizing that] the likelihood for policy borrowing increases when incremental reforms fail, leaving policy makers with a protracted policy conflict that brings any further attempts at reform to an impasse. In such moments of protracted policy conflict, they construct an ‘absent other’ by resorting to an imagined world culture in education as if there exists an international agreement on how reforms in education are supposed to unfold” (p. 4).

Theisen and Adams (1990) consider that comparative education tends to be influenced by diverse theoretical perspectives, either directly through the framing of research questions or indirectly through the implicit assumptions of the researcher. Among the theories most prominently employed in comparative education are functionalist theories, Marxist and Neo-Marxist theories, dependency and world systems theories, and interpretist theories (Theisen & Adams, 1990, p. 285).

Functionalist Theories. Such theories draw from mainstream social science and tend to explain social change as a gradual process of structural differentiation and specialization. They have been widely influential in comparative education research: human capital models (Bowman & Anderson, 1968, p. 113-131), modernization models (Inkeles & Holsinger, 1974), and production function models (Leigh & Simmons, 1975; Heyneman & Loxley, 1983). These theories generally treat education as a good that benefits the individual and contributes to the public wealth.

Marxist and Neo-Marxist Theories. Conceptions deriving from the dialectical materialism of Karl Marx, these theories assume that tensions and contradictions between groups and classes in society are always present and, when sufficiently intense, set the stage for radical change. Education is viewed as a means of legitimizing social and economic inequities and of maintaining stasis in the existing social structure (Carnoy, 1974).

Dependency and World Systems Theories. Such theories emphasize the interdependence of countries and the tendency of core, industrialized nations to influence or control “peripheral” less industrialized ones. Education in periphery nations reflects the hierarchical relationships and dependent linkages to the economy and culture of the core nations (Wallerstein, 1979; Arnove, 1980). Some comparative scholars have suggested that a world knowledge system exists, with scholars, academics, and professionals from the periphery linked to the center in a web of inequality (Altbach, 1978).

Interpretist Theories. Functionalist, Marxist, and dependency theories often share a view that reality is concrete and defined by tangible, empirically defined facts. Interpretist and humanist theories emphasize the subjective nature of reality and the need to study educational systems in terms of what education means to those who participate in the process, namely the individual students and teachers (Berger et al., 1973; Popkewitz, 1984).

Theisen and Adams (1990) conclude that:

“conceptually, all of these major theoretical trends owe their origins to the work done in other social science disciplines, but the application of them to multiple education settings in order to understand better the education-society nexus has been a unique contribution of comparative educators” (p. 285).

At a more descriptive level, different authors present different definitions based on complementary visions of comparative education. Awolola (1986) describes it as the study of goal and purpose of education, the curriculum methods of teaching, school calendar, access to internet, teacher-student relationships, school administration, among others, at the international or national levels. Adeyinka (1994) considers a more formal definition in comparative education as quoted below¹:

- “a) A study of two or more education systems.
- b) A study of how the philosophy, objectives and aims, policy and practice of education in other countries influence the general development, policy and practice of education in a particular country.

¹ www.google.com: Adeyinka (1994). Retrieved on 19 May, 2013. From http://www.nou.edu.ng/noun/NOUN_OCL/pdf/EDUs/EDU%20314%20-%20COMPARATIVE%20EDUCATION.pdf

- c) A study of how the development of education in the past, across the ages and continents, has influenced the development of education in particular countries.
- d) A study of the school systems of two or more countries, and of the administrative machineries set up to implement or to control the implementation of government policies at various levels of education systems”.

Another well-known attempt to present the complexities of the field was the proposal of Bray and Thomas (1995) of a framework for comparative education analysis depicted in a three-dimensional cube (see Figure 2) that combines (i) geographical/ locational levels, from individuals and classrooms to countries and regions, (ii) non - locational demographic groups, based on gender, ethnicity or other variables, and (iii) relevant aspects of education and society, from the curricula to political change or labor market. The cube represents “a call for multilevel analyses in comparative studies to achieve multifaceted and holistic analyses of educational phenomena” (Bray, Adamson & Mason, 2007, p. 8) and clearly helps researchers in the field to develop a more conscious recognition of the various levels and intersections between them in comparative studies.

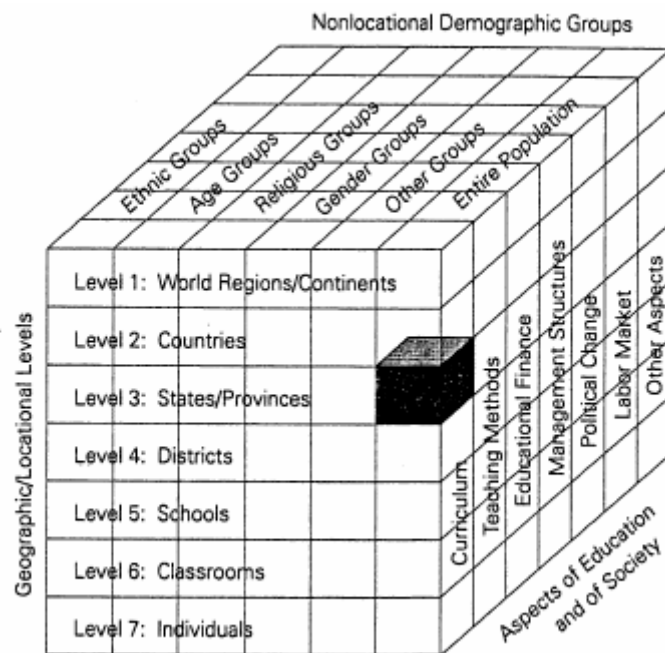


Figure 2. Bray and Thomas' framework for comparative education analyses (Bray & Thomas, 1995, p. 475)

The obvious articulation with other disciplines, such as international education, development education or comparative sociology, justifies Wilson's (2003) proposal of comparative education as "an intersection of the social sciences, education and cross-national study which attempts to use cross-national data to test propositions about the relationship between education and society and between teaching practices and learning outcomes" (p. 17). Epstein (2008), however, considers that there is a lack of epistemological reflection within the discipline, that is characterized by particularly 'fluid boundaries' and could be defined as "the

application of the intellectual tools of history and the social sciences to understanding international issues of education” (p. 382) with different research traditions conceptualizing the normative character of the discipline in diverse forms, from considering the goal is to generalize (positivist) to emphasizing the impossibility of such task (relativist), or trying balance (historical functionalist) or even move “beyond the normative” (p. 383).

Phillips (2006) also presents a classification of comparative education research based on the purpose of the research, and identifies four different categories: 1) analytical research; 2) descriptive research; 3) evaluative research, and 4) exploratory research (see Table 1).

Table 1. Criteria for Classification of Comparative Education Research (Phillips, 2006, p. 306)

Research Type	Typical Questions	Purpose of Research
Analytical	What are the explanations for relationships between components?	Description of roles.
	Why do actors or systems behave in the way they do?	Specification of cause - and - effect relations or explanation of relations and consequences.
Descriptive	What is the current status of the phenomena?	Description of phenomena or conditions.
	What are the relationships between variables?	Description of relations between variables.
Evaluative	Is program A better or more cost effective than program B?	Judgment of the merit, value, or worth of any given program or technique.
	Is the program or policy appropriate for a particular context?	Interpretations useful for decision making.
Exploratory	What issues pertaining to roles, relationships, and processes exist which are worthy of examination by other modes of research?	Generating new hypotheses or questions.
	What models, paradigms or methods might be useful in designing future research?	Exploration of relationships and functions with potential for other in-depth research.

On the whole, both cross-national and historical comparisons of education systems usually place considerable emphasis on the social, economic and political contexts. For example, Crossley and Jarvis (2001) have emphasized that “the significance of context, at all levels and in many forms” (p. 405). Likewise, Le Métais (2001) observed that “the context (...) goes a long way to explain the success or failure of specific teaching and learning approaches” (p. 197), and therefore consideration of the context is necessary for cross-national comparisons, as well as intra-national ones, as there is no such thing as homogeneity in culture (Mason, 2007). However, international large-scale studies such as PISA have been criticized for their inability “to understand the cultural, historical and social contexts” of the research (Zhao et al., 2008, p. 1), while it is expectable that “educational results are not explained only by individual differences between students but also by the differences in educational contexts” (Täht & Must, 2013, p. 30). In fact, as Mason (2007) argues, the cultural context is central to deeply understand variations in educational phenomena, and this poses significant challenges to the comparative education researcher, that range from ethical and deontological factors, to phenomenological and methodological dimensions, suggesting the need for a multidisciplinary approaches. In fact,

“comparative educational research across cultures will perhaps be stronger for its acknowledgement that it is not only research *about* two or more cultures, in the cross-cultural sense, but also, inevitably, research that is intercultural in nature, in that it is about perspectives *from* the

cultures under study, and *from* the cultural perspectives of the researchers” (p. 192).

3. Some examples of comparative education studies using PISA

As we said in the introduction of this chapter, large-scale comparative studies implemented by the IEA and, more recently, the OECD gave a definite impulse to the field of comparative education, even if the challenges of developing comparable goals, instruments, populations, samples, ... are immense, as studies risk ‘comparing the incomparable’ (Postlethwaite & Leung, 2007). To conclude this chapter, we decided to briefly illustrate the potentials – and surely the limits – of the use of PISA in comparative research. However, it is clearly beyond the scope of this chapter to give a complete picture of the PISA-related comparative research, an impossible task given the amount of literature: for instance, a simple search using three databases from EBSCO (Academic Search Complete, Education Research Complete, and PsycINFO) shows that, from 2009 to 2012, approximately 1500 papers were published with a reference PISA in either the title or abstract. Therefore, we will only shortly refer some examples.

The Belgium researcher Vincent Dupriez has been conducting a series of very interesting studies using PISA databases to consider social inequalities in education. In 2006, Dupriez and Dumay used the PISA 2000 database to consider whether the inequalities in school systems were an effect of school structure or of society structure. The point of departure was the fact that equality of opportunities

of educational achievement is higher in integrated school systems than in differentiated school systems, as pupils' achievement in integrated school systems appears to depend less on their family's social and cultural resources. Results show that integrated schools systems are more egalitarian, resulting in students' achievement being less determined by family background.

In another research with PISA 2003, Dupriez et al. (2012) explored inequalities of post-secondary educational aspiration in a group of OECD countries to consider whether (i) educational aspirations had been influenced by pupils' socio-cultural background and (ii) if the residual influence of socio-cultural background is still significant after controlling for educational achievement. The socio-cultural and academic characteristics of school composition were estimated to have an additional impact on educational aspirations. Results show that the structural characteristic of school systems moderates the influence of individual characteristics and school composition on educational aspiration.

Another interesting research has been conducted by Fredriksson et al., (2009) comparing two countries in Europe, Sweden and Switzerland, two of the most wealthiest countries in Europe. Besides the similarity, the distinctive image of these two countries that motivated the study is that Sweden and Switzerland follow different social welfare model, social democratic in Sweden and liberal in Switzerland. These differentiations brought attention on how the educational systems in these two countries have been organized; in consequence, the purpose of the study is to compare the ability in comprehensive reading and mathematics of

students in the light of supportive data from OECD, and PISA 2000 has been used. The data show that 97% and 99% of 15-year old student are enrolled in the educational system in Sweden and Switzerland, respectively. There are high percentages in reading ability for girls in both countries; regarding mathematics, the opposite occurs with boys having better results – but this gender gap is larger in Sweden for reading and in Switzerland for mathematics.

Marks et. al. (2006) consider the relationship between material, social and cultural resources and students performance, including factors such as the financial security of the family, access to school materials or learning equipment, parental and community participation within school. The data from OECD has been analyzed by using PISA 2000, with data from 32 countries, and considering students' achievement in reading and mathematics. Results show that cultural factors play the most important role in students learning achievement in most of the sampled countries, and material resources have a substantial impact, while social resources have very little impact – a relationship that tends to be stronger in countries with a high tracked system. Some components of school system (the curriculum, structure, management and so on) mediate the relationship between socioeconomic background and student achievement.

Several studies investigated the relationship between students performances and socioeconomical background of the family, but there is not much attention to other factors that may have some negative impact on students learning achievement. Montt (2011) evaluated whether two dimensions of schooling – that

vary across education systems –, opportunities to learn and intensity of schooling, are associated with achievement inequality independently of family background. He examined country to country differences in total achievement inequality, using data from PISA 2006 in more than 50 countries. The finding suggest that both variables are related to a reduction in total achievement inequality: this means that achievement equality is fostered by opportunity to learn, particularly in the form of equality in the distribution of quality teachers across schools and absence of tracking, and greater intensity of schooling, especially when the quality of teachers across the system is strong.

On the whole, whether using the large samples from many countries or focusing on comparisons between a smaller group, PISA has become incredibly popular as a source of secondary data analysis in education.

4. Conclusion

In this chapter, we have considered the field of comparative education and its potentials and limits for the advancement of educational theory and research. In a globalized world such the one we live in, the significance of comparative education has particularly increased – and for this the implementation of large-scale studies by international agencies such as the IEA and the OECD has been extremely relevant. It is therefore not surprising that we have followed that path and decided to conduct a comparative study on European and Asian countries

using the PISA 2006 database. However, the focus of PISA 2006 was on scientific literacy, and therefore in the next chapter we will consider the definitions of scientific literacy and the way it is operationalized in this study.

CHAPTER II

SCIENTIFIC LITERACY

The world has dramatically changed over the past centuries due to the industrial revolution, scientific development and social-cultural transformation. These changes were accompanied by an exponential growth of knowledge and innovation, and therefore the research about learning in schools (and beyond) has become an important topic as science is more and more a part of everyone's everyday life.

There are several studies about scientific literacy in the literature. This chapter will focus mainly on the review of scientific literacy, highlighting its meaning and importance and exploring the diversity of theoretical conceptions. Then, the PISA 2006's understanding of scientific literacy will be analyzed in more detail, including the PISA 2006 Framework for assessing scientific literacy.

1. Historical evolution of the concept of scientific literacy

Scientific literacy has developed gradually for several decades and is now widely used in science education (Millar, 2006; Bybee et al., 2009; Bybee & McCrae, 2011).

A report published by Rockefeller Brothers Fund in 1958 explored the ways in which the United States should respond to the rapid scientific and

technological changes in areas like nuclear energy and aerospace engineering. It argued that although such fields needed highly skilled personnel, a technically trained workforce was particularly important to catch up with rapid changes in science (DeBoer, 2000). An article published in the same year by Hurd (1958) stressed the importance of providing education in a quickly changing world and science played an important role in society. He pointed out that children's learning experiences at schools should foster "the development of an appreciation of science as an intellectual achievement, and as a procedure for exploration and discovery" (p. 16). In Hurd's definition, scientific literacy meant that an understanding of science and its impacts on social life, values, politics and economic problems, is essential in order to understand science and be able to adapt in society as science and technology highly influence decisions in many areas such the economy, politics, and personal life.

Hurd's article can be considered a milestone on the field. Afterwards, scientific literacy has been used to explain science education in term of purposes, policies, programs, and practices. However, this approach cannot represent the "ultimate" meaning for scientific literacy nowadays, as researchers still have arguments regarding what scientific literacy means. In the United States, there is evidence that the purpose and practice was not successful to achieve the objectives of science education (Millar, 2006; Bybee et al., 2009; Bybee & McCrae, 2011).

In 1963, Robert Carleton, executive secretary of the National Science Teachers Association (NSTA), surveyed a group of scientist and science educator

to describe scientific literacy. The majority of the answers indicated that one who has scientific literacy should have some broad knowledge of science fields, while only a small number of responses mentioned science-society relationships and the process of conducting a scientific study (Garfield, 1988). A literature review by Pella, O'Hearn and Gale (1966) examined 100 articles to determine the components meaning of the term and conclude that the most important "components" of scientific literacy were: 1) interrelations between science and society, 2) ethics of scientific study and 3) nature of science.

The National Science Teachers Association (NSTA) (1971) declared that the main characteristics of a scientifically literate person are using scientific concepts in decision making. Moreover, they also have a better understanding of the relationship between science, technology, and other elements of society such as social and economic development. Although the idea that science education should be tied with social life was well established, it gained popularity when the NSTA announced it as the most significant purpose of science education in its position statement, *School Science Education for the 1970s* (DeBoer, 2000).

Shen (1975) suggested that scientific literacy has three categories: practical, civic, and cultural. *Practical scientific literacy* consists of the "possession of the kind of scientific knowledge that can be used to help solve practical problems" (p.46), and knowledge addressing the basic necessities of life, like food and shelter; *civic scientific literacy* has to do with having enough knowledge to use in decision making processes related to social issues such as health and natural

resources; *cultural scientific literacy* refers to having knowledge about the scientific ideas that lead to major achievements.

Later, Miller (1989) pointed out that scientific literacy does not indicate a perfect level of understanding and proposed that scientific literacy should be functional. In society, an individual with functional scientific literacy such as a citizen or consumer has at least a basic understanding of science and technology. Miller stated that functional scientific literacy had three dimensions: 1) understanding the process of science, 2) understanding basic scientific terms and concepts, and 3) understanding the impact of science in society and on individuals in coping with public policy issues.

2. Contemporary debates and controversies

Until today, however, the concrete definition of scientific literacy remains controversial. Many academic researchers propose several definitions, although relatively close, but there is no actual agreement on the meaning of scientific literacy. For example, scientific literacy may also be defined in terms of a framework consisting of four aspects: 1) the knowledge of science, 2) the investigative nature of science, 3) science as a way of thinking, and 4) interaction of science, technology and society (Boujaoude, 2002; p. 146). Millar (1997) suggested that scientific literacy should be considered as the level of understanding of science and technology needed to function as a citizen. Norris & Philips (2003) stated that the goal of science education can be expressed as scientific, or scientific

literacy and technology literacy. When it comes to defining the term, the discussion becomes more complex (Millar, 2006; Searce, 2007). According to Bybee (1997) scientific literacy has defied precise definition not only because it is a broad concept encompassing many educational themes, but also it has been used as a slogan to support more and better science teaching. Various authors have stated that the purpose of scientific literacy should be consistent with the purpose of science education (Bybee et al., 2009).

In 1998, Hurd summarized the 350 year history of studies to tie academic science with its applications to real life, and concluded that scientific literacy is “a process of acquiring, analyzing, synthesizing, coding, evaluating, and utilizing achievements in science and technology in human and social context” (p. 414). Important characteristics of a person who has scientific literacy can be summarized in Table 2 below.

Table 2. Characteristics of a scientifically literate person (Hurd, 1998, p. 413)

Characteristics of a scientifically literate person				
1) Recognizing		2) Distinguishing	3) Knowing	
1.1 About the nature of scientific knowledge	1.2 About the use of scientific knowledge		3.1 About the nature of scientific knowledge	3.2 About the use of scientific knowledge
• Symbiotic relationship between science, technology and human affairs	• When more data is needed to make valid judgments.	• Evidence from propaganda	• Science problems in social contexts may have more than one “right” answer	• How to analyze and process information to generate knowledge and go beyond facts
• Scientific knowledge has limits and risks	• When causal relationship cannot be drawn.	• Theory from dogma	• Science in social contexts is multidimensional (political, judicial, ethical and sometimes moral)	
• Science produces cumulative and falsifiable	• The importance of collaboration to solve science- social problems.	• Data from myth and folklore		
	• That a synthesis of knowledge from various social and scientific fields is needed to solve social problems.	• Knowledge vs. opinion		

Two major reports published in the last decade of the 20th century have also concentrated on the importance of scientific literacy. One of these is the *Project 2061: Science for All Americans* (Rutherford & Ahlgren, 1990). This science education project aimed at not only describing philosophical views, but, above all at curriculum development, science teaching and learning, and teacher education. The Project produced several papers by the American Association for the Advancement of Science (AAAS) stating that schools need to focus on scientific literacy and to teach more effectively than teaching just more content.

The second publication was a summary report of a seminar that took place in England in 1997: *Beyond 2000: Science Education for the Future* (Millar & Osborne, 1998). Science educators discussed four principal questions regarding the science education in that country:

“1) What are the successes and failures of science education to date? 2) What science education is needed by young people today? 3) What might be the content and structure of a suitable model for a science curriculum for all young people? and 4) What problems and issues would be raised by the implementation of such a curriculum, and how might these be addressed ?” (p. ii).

The main suggestion of this report is that increasing scientific literacy should be the main purpose of the science curriculum for all pupils from age 5 to 16.

DeBoer (2000) has provided a historical and contemporary review of scientific literacy, referring that the purpose of scientific literacy has been changed due to the massive change of the society. Millar (2006) mentioned definition issues of scientific literacy before publishing *Twenty First Century Science*. For him, there are significant attributes in the curriculum of science education that comprise content (e.g., epidemiology, health), qualitative understanding, and a solid knowledge about science.

In the United States, there are two seminar essays in the discussion about contemporary science education and scientific literacy. In the first essay, “*Science Education for the Twenty First Century*” Osborne (2007) considers that contemporary science curricula and practices are primarily “foundationalist”, that is, the curricula tend to favor educating future scientists *over* educating future citizens. The writer of the second essay, Roberts (2007), in the *Handbook of Research on Science Education* (Abell & Lederman, 2007), revises these two opposing traditions by asking: Should the curriculum emphasize scientific contents as such or should it link to life situations that depend on a scientific perspective? Obviously the former assumes “future scientists” as the target group, while the latter aims “future citizens”.

With several publications in the area, Bybee (1997; Bybee et al., 2008) identified four dimensions of scientific literacy: nominal, functional, conceptual and procedural, and multidimensional. He proposed that the goal of science curriculum could be improved by increasing scientific literacy level of students

from illiteracy or nominal literacy to multidimensional literacy. Table 3 presents the dimensions of scientific literacy in Bybee's view.

Table 3. Dimensions of scientific literacy (Bybee et al., 2008, p. 92)

Dimensions of scientific literacy	
Nominal	
	• Identifies terms, questions, as scientific but demonstrates incorrect topics, issues, information, knowledge, or understanding. • Has misconceptions of scientific concepts and processes. • Gives inadequate and inappropriate explanations of scientific phenomena. • Expresses scientific principle in a naive manner.
Functional	
	• Uses scientific vocabulary. • Defines scientific terms correctly. • Memorizes technical words.
Conceptual and Procedural	
	• Understands conceptual schemes of science. • Understands procedural knowledge and skills of science. • Understands relationships among the parts of a science discipline and the conceptual structure of the discipline. • Understands organizing principles and processes of science.
Multidimensional	
	• Understands the unique qualities of science. • Differentiates science from other disciplines. • Knows the history and nature of science disciplines. • Understands science in a social context.

3. The importance of scientific literacy

In spite of the diversity of definitions that we demonstrated above, scientific literacy is one of world most recognized education slogan and goal, even if the concept can be named as “public understanding of science” (in the UK) or “la culture scientifique” (in France) (Durant, 1993). Scientific literacy “stands for what the general public ought to know about science” (Durant, 1993, p. 129) and “commonly implies an appreciation of the nature, aims and general limitations of science, coupled with some understanding of the more important scientific ideas” (Jenkins, 1994, p. 5345).

From the past until now, as we have seen, many researchers debate on its meaning, but there has been a general agreement on the importance of scientific literacy (Bybee, 1997; Millar & Osborne, 1998; Dos Santos, 2008; Murcia, 2009). Laugksch (2000) summarized the arguments at two levels: macro and micro. The former relates to benefits to the country, society, and science; while the latter relates to the enrichment to the lives of the individual.

As indicated in the beginning of this chapter, a reason for promoting scientific literacy is its relationship with economic development of country, the macro level. Laugksch (2000) argued that competing successfully in international markets ultimately depends on a strong national research, development, and production programs and a labor market with engineers, scientists and specialized workers. The second macro level advantage of greater scientific literacy concerns

public expectations of science. Laugksch (2000) stated that when the public are capable of understanding “the objectives, processes, and capabilities of science” (p. 85), they will develop realistic and realizable expectations, which are associated with a strong support for science. The third macro level reason refers to the relationship between science and culture (Thomas & Durant, 1987). Laugksch stressed that effective integration of science in the culture is crucial for the health of a society. If science is separated from the particular culture, the public not only fails to understand its role and importance but also may see it more as only an area of specialization, thus creating a mixture of fear and adulation. The last macro level factor is related to science itself. Laugksch believed that scientifically literate individuals are more likely to value science and support spending public funds for scientific studies. However, Schibeci (1989) considers that this expectation is unrealistic, as individuals with some level of scientific understanding are “likely to approve of some aspects of science but not of others. If understanding is empowering, it is naive to suppose that there is an automatic link between understanding and approval” (p. 246).

Regarding the micro level benefits, Laugksch (2000) considers that with an increase in scientific literacy, a person can deal more confidently and competently with daily life’ science and technology. More scientifically literate individuals can make informed decisions about personal choices, for example, about smoking, diet and vaccination – but again this view could be considered naive, as it supposes that life decisions are solely based on rationality – and be

more open to benefits resulting from technical developments and challenges in work contexts. The second micro level benefit is related to individual's intellectual capacity and aesthetic view. Laugksch (2000) considers that in the 20th century a basic of being an educated person requires knowledge of science. Scientific literacy is believed to enable one to express feelings in creative and impressive ways through fine arts such as painting and photography (Shortland, 1988). Trefil (2007) illustrated a photographer can take exciting pictures of space or an artist can reflect his inspirations from molecular science in his drawing.

Not surprisingly, many researchers have proposed that science curriculum in schools should focus on scientific literacy (Bybee, 1997; Cross & Pierce, 1999; Roth & Lee, 2004), and some argued that school curriculum should even go beyond that and create a discussion around social and political issues in relation to science (Freire, 1994; Dos Santos, 2008). For example, students should be able to think on and discuss about global and political problems and ask questions like “Why do rich nations produce a lot of waste, whereas in other nations there is not enough food for their inhabitants? Why are the natural resources and the workers from Third World nations exploited by multinational industries?” (Dos Santos, 2008, p. 379).

The discussion on scientific literacy emerges from, and feeds itself in, two politically conflicting emphases about science curriculum. Some argue that curriculum should emphasize a science subject for itself; others, on the contrary, argue that it should emphasize science in real life issue in which science plays a

important role (Abell & Lederman, 2007). PISA 2006 represents the vision of scientific literacy as educating future citizens, that is, the point of view of science applied in real life situations.

4. PISA's view on scientific literacy

PISA defines scientific literacy as “the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity”(OECD, 2006, p. 25). Consequently, apart from determining students' knowledge, PISA also examines students' ability to reflect on their knowledge and experience as well as to use that knowledge and experience on their real world's life.

The Organization for Economic Cooperation and Development (OECD) choose to assess student's scientific literacy instead of science knowledge because scientific literacy best represents the importance of science education (Harlen, 2001; Millar, 2006). The main question that PISA 2006 assessment of 15-year-old students purposed to answer was: “What is it important for citizens to know, value, and be able to do in situations involving science and technology?” (OECD, 2006, p. 20).

For the purpose of PISA 2006, scientific literacy referred to four interrelated features that involve an individual's:

- “Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomenon, and draw evidence-based conclusions about science-related issues.
- Understanding of the characteristic features of science as a form of human knowledge and enquiry.
- Awareness of how science and technology shape our material, intellectual, and cultural environments.
- Willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen” (OECD, 2006, p. 23; OECD, 2009, p. 128).

Scientific literacy has been defined in PISA 2006 into four interrelated components: Context, Knowledge, Competencies, and Attitudes.

- **“Context:** Recognizing life situations involving science and technology.
- **Knowledge:** Understanding the natural world on the basis of scientific knowledge that includes both knowledge of the natural world and knowledge about science itself.
- **Competencies:** Demonstrating scientific competencies that include identifying scientific issues, explaining phenomena scientifically, and drawing conclusions based on evidence.
- **Attitudes:** Responding with an interest in science, support for scientific enquiry, and motivation to act responsibly towards, for

example, natural resources and environments” (OECD, 2006, p. 25;

OECD, 2009, p. 130; Bybee & McCrae, 2011, p. 9).

Consequently, PISA 2006 takes into account 4 following interconnected elements:

- Scientific context of assessment of science which is the perception of daily situations which are related to science and technology.
- Scientific competencies refer to the application of knowledge to identify scientific issues, explain scientific phenomena and to use scientific evidence.
- Scientific knowledge contains two main parts as in knowledge about the natural world or “*knowledge of science*” and knowledge about procedure and strategy to seek such knowledge of science, namely, “*knowledge about science*”.
- Attitudes toward science refer to the response to science issues with interest, support for scientific enquiry and responsibilities towards various things such as natural resources and environment.

All four elements for the science assessment are interrelated. In other words, context is about the life in students live and the situations that force people to gain scientific competencies to encounter or react; how well one can respond

depends on the influence of knowledge and attitudes of each person. The relationship of all elements is shown in Figure 2 below.

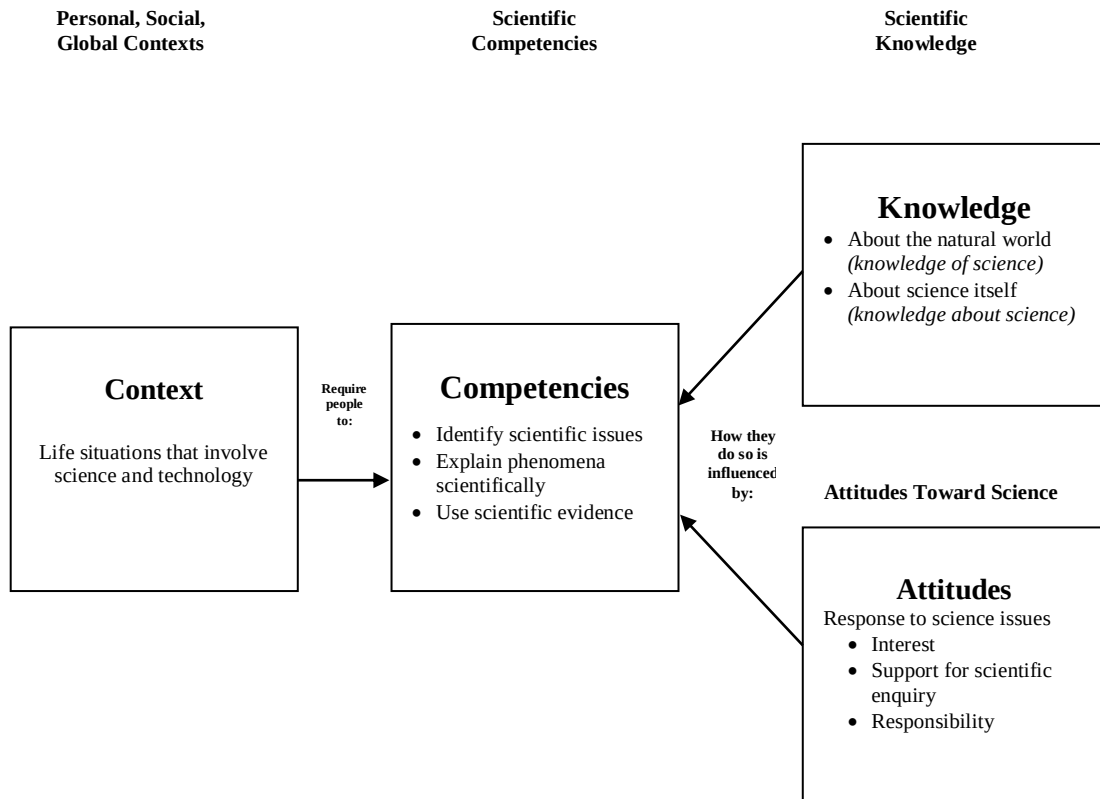


Figure 3. Framework of PISA 2006 science assessment (OECD, 2006, p. 26)

All elements in Figure 2 are interrelated in many different dimensions about scientific literacy. Although students have learned about science and gained such knowledge in scientific situations or contexts, in real life students can perceive relevant information about science from various media and they can have

an analytical thinking to express their scientific literacy. Students need scientific competencies to manage or make a decision about the contexts of science and technology. To achieve scientific competencies, students need knowledge and attitudes toward science.

The framework of PISA 2006 science assessment, results in the questions that are limited into the following frames:

- What contexts should be assessed for 15-year-old students?
- What scientific competencies are 15-year-old students expected to demonstrate?
- What scientific knowledge should 15-year-old students be able to demonstrate?
- What attitudes toward science should 15-year-old students to demonstrate?

PISA 2006 is the first international study about competencies, interest and attitudes toward science, as well as the contexts of school and approach to teaching science in relation to the global context. Therefore, there can be information about how scientific literacy of students varies in each country, in each context, for each approach to presenting science or teaching science, as well as how each context is related to students' learning.

4.1 Scientific contexts

Scientific situations and contexts are important for the application of scientific knowledge: the main part of scientific literacy is the relationship with science in various situations to deal with scientific issues. Therefore, the choice of approach often depends on the situation of such problem. The same problem in different situations might result in different approach.

The situation or context or setting is one part of task in real life of students. The framework of PISA rests on the development of learning theory (OECD, 2006) that stresses that knowledge does not just appear by itself but according to a specific situation or context, and therefore testing requires situations or constraints of the task context for assessment. The question is not for testing knowledge or understanding of scientific contents as given in the curriculum, but for using science in real life such as with the students themselves, family or friends (personal context), in hot issues which influence society, culture, health or human life (social context), as well as science in news or science which will have an impact on world society or future (global context).

To raise a question for assessment must be confined to a situation in the student's world. PISA 2006 questions are not limited to only situations in school, but situations which might concern the students themselves, in their family, community, as well as the world. Even questions about history and the understanding of science can be raised for assessment. Table 4 describes the contexts for PISA 2006.

Table 4. Contexts for the PISA 2006 science assessment (OECD, 2007, p. 36)

Context	Personal (Self, family and peer groups)	Social (The community)	Global (Life across the world)
Health	• Maintenance of health, accidents, nutrition	• Control of disease, social transmission, food choices, community health	• Epidemics, spread of infectious diseases
Natural resources	• Personal consumption of materials and energy	• Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	• Renewable and non-renewable, natural systems, population growth, sustainable use of species
Environment	• Environmentally friendly behavior, use and disposal of materials	• Population distribution, disposal of waste, environmental impact, local weather	• Biodiversity, ecological sustainability, control of pollution, production and loss of soil
Hazard	• Natural and human-induced, decisions about housing	• Rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment	• Climate change, impact of modern warfare
Frontiers of science and technology	• Interest in science's explanations of natural phenomena, science-based hobbies, sport and leisure, music and personal technology	• New materials, devices and processes, genetic modification, weapons technology, transport	• Extinction of species, exploration of space, origin and structure of the universe

4.2 Scientific competencies

PISA 2006 is the first international study that surveys the scientific competencies of students, assuming that scientific literacy is related to certain intellectual capabilities such as inductive/deductive reasoning, critical and integrated thinking, transforming (such as inputting data into table), converting (tables into graphs, etc.), constructing and communicating arguments and explanations based on data, thinking in terms of models and using mathematics.

PISA defines the assessment of scientific competencies as how well students can perform the following tasks:

1. Identifying scientific issues (ISI)
2. Explaining phenomena scientifically (EPS)
3. Using scientific evidence (USE)

PISA 2006 places the first priority on scientific competencies which are considered to have a role in enabling people to use knowledge for decision-making and communicating scientific contents. These scientific competencies can emerge only when scientific knowledge lies as the basis. These are *knowledge of science* and *knowledge about science* for knowledge enquiry. Table 5 describes the several features of the three competencies.

Table 5. PISA 2006 Scientific Competencies (OECD, 2007, p. 37)

Identifying scientific issues (ISI)
• Recognizing issues that it is possible to investigate scientifically • Identifying keywords to search for scientific information • Recognizing the key features of a scientific investigate
Explaining phenomena scientifically (EPS)
• Applying knowledge of science in a given situation • Describing or interpreting phenomena scientifically and predicting changes • Identifying appropriate descriptions, explanations, and predictions
Using scientific evidence (USE)
• Interpreting scientific evidence and making and communicating conclusions • Identifying the assumptions, evidence and reasoning behind conclusions • Reflecting on the societal implications of science and technological developments

The main thing for living in a science-based society is the ability to distinguish scientific issues or topics from other kinds of issues (ISI). The scientific issues are the things which can be answered through scientific evidence. One of the most important scientific competencies is to identify scientific issues which include the following abilities:

1.1 “*Knowing which questions or problems can be answered through science.*

This type of assessment question would like students to distinguish scientific questions/ problems from other types of questions which are not related to science.

Such competency wants students to identify which question can be tested scientifically. Students can suggest an approach to seek an answer to the problem.

1.2 *Telling a Keyword for Searching*. To identify which question can be checked scientifically, students must be able to tell a keyword for searching and to find a tool for checking, that is to say, to be able to identify which information, evidence or witness to check. This competency wants students to answer what information, contents, witness and evidence students need in order to answer the question so that they can plan a correct way to collect the data.

1.3 *Knowing the main characteristics of scientific verification*. To show their ability to check scientifically, students must know the main characteristics of verification such as know how to do a valid test, what to compare, what variable to control, and what variable to change. Students must seek more information and contents and know what to do and how to do to collect the desired data” (OECD, 2006, p. 30).

Explaining phenomena scientifically (EPS) includes the ability to describe, interpret a phenomenon, and expect or predict changes which might occur. The assessment will include the students’ ability to identify which and how a description is reasonable, whether the prediction is likely to occur and through what reason, and the like. For example, in a crime situation in which DNA needs to be verified, students need to use scientific knowledge to identify which descriptions about DNA is appropriate.

Using scientific evidence (USE) implies students know the meaning and the significance of the things which are found or discovered through science and use them as a basis for thinking, concluding, retelling and communicating through the use of knowledge, either knowledge about science or knowledge of science, or both. The use of scientific evidence also refers to the following abilities:

3.1 *“Knowing which scientific evidence to use.* This shows that students understand what data or evidence from the investigation and data collection can be used as a basis for telling, concluding, predicting or expecting and making a contradiction.

3.2 *Reaching a reasonable conclusion.* Students reach a reasonable conclusion on the basis of evidence, data or assessment of the conclusion made by others to compare whether it complies with the evidence or not. This type of question might ask students to analyze and criticize the conclusions given to them by analyzing whether such conclusions are from the specified data or not or by giving data or evidence and asking students to reach a conclusion from the given data and evidence. Students can also give reasons to analyze and criticize the conclusion to show either agreement or disagreement.

3.3 *Communicating a conclusion.* Communication is intended for specific information or conclusion derived from evidence. The data will be related to how to describe and make a contradiction for the situation and the given information by communicating it clearly to the data receivers.

3.4 *Showing that they understand scientific concepts.* This aspect will assess students in terms of scientific concepts by examining whether students could apply such concepts in the given situation, what is the description to show the

relationship or the cause of change, or what is the prediction of the next event if there is a change in one variable, or what variable or factor has a role in leading to such result. Students are expected to use scientific concepts (which are not given) to explain” (OECD, 2006, p. 30).

4.3 Scientific knowledge

PISA 2006 states that assessment of scientific knowledge must cover two types of scientific literacy: 1) knowledge of science and 2) knowledge about science. *Knowledge of science* covers the concepts and bodies of knowledge about the natural world such as physical system, physics, chemistry or biological system such biology. *Knowledge about science* refers to the knowledge about approach or the procedure to gain knowledge of science or the way to reach such goal of knowledge acquisition. Although there are many scientific concepts, the assessment by PISA focused only on the relevant concepts and contents for living in the future which will help understand the scientific aspects of the world. It focused on the clarity, the practicality and the usability in the future as well as the suitability for 15-year-old students.

Therefore, the concepts and the contents chosen by PISA for assessment are not only applicable to today, but also applicable to the next decade and the future. Although science assessment is the main focus in PISA 2006, the concepts chosen for assessment must be of significance to science courses and public policies from 2006 onwards. Besides, the criteria used for choosing the contents

for assessment by PISA are not related to the knowledge or the memory or the main concepts, the definitions or the scientific facts. Rather, the criteria are related to four main aspects which involve daily living of common people and are visible in social issues or the media which are normal way of life in the current and future societies. The assumption is that people receiving the news must have a basic understanding to perceive the contents and the information from the media and to be able to analyze and make a judgment on such topics or issues. Therefore, these four aspects should be used to cultivate thinking process and decision-making about sciences to students.

Knowledge of science for assessment by PISA must cover the knowledge of natural world as given in Table 6 below.

Table 6. PISA 2006 knowledge of science categories (OECD, 2007, p. 38)

Physical systems
• Structure of matter (e.g., particle models, bonds) • Properties of matter (e.g., changes of state, thermal and electrical conductivity) • Chemical changes of matter (e.g., reactions, energy transfer, acids/bases) • Motions and forces (e.g., velocity, friction) • Energy and its transformation (e.g., conservation, dissipation, chemical reactions) • Interactions of energy and matter (e.g., light and radio waves, sound and seismic waves)
Living systems
• Cells (e.g., structures and function, DNA, plant and animal) • Humans (e.g., health, nutrition, disease, reproduction, subsystems(such as digestion, respiration, circulation, excretion, and their relationship)) • Populations (e.g., species, evolution, biodiversity, genetic variation) • Ecosystems (e.g., food chains, matter and energy flow) • Biosphere (e.g., ecosystem services, sustainability)

Table 6. (Cont.)

Earth and space systems
• Structures of the earth systems (e.g., lithosphere, atmosphere, hydrosphere) • Energy in the earth systems (e.g., sources, global climate) • Change in the earth systems (e.g., plate tectonics, geochemical cycles, constructive and destructive forces) • Earth’s history (e.g., fossils, origin and evolution) • Earth in space (e.g., gravity, solar systems)
Technology systems
• Role of science-based technology (e.g., solve problems, help humans meet needs and wants, design and conduct investigations) • Relationships between science and technology (e.g., technologies contribute to scientific advancement) • Concepts (e.g., optimization, trade-offs, cost, risk, benefit) • Important principles (e.g., criteria, constraints, cost, innovation, invention, problem solving)

These types of knowledge are important for the understanding of the natural world and to give meaning to the experiences encountered in the personal, social and global contexts. That is why the word “system” is more preferable than science for the disciplinary knowledge, as it is used to signify the meaning that the citizen must understand the scientific concepts in many disciplines, not just the contents.

Knowledge about science according to PISA is defined as the reflection on the nature of knowledge about science as enquiry or the procedure to gain knowledge. Therefore, knowledge about science is procedural knowledge which consists of scientific enquiry, based on scientific process, and scientific

explanation, following knowledge enquiry. The structure is given in Table 7 below.

Table 7. PISA 2006 knowledge about science categories (OECD, 2007, p. 39)

Scientific enquiry
• Origin (e.g., curiosity, scientific questions) • Purpose (e.g., to produce evidence that helps answer scientific questions, such as current ideas, models and theories to guide inquiries) • Experiments (e.g., different questions suggest different scientific investigations, design) • Data (e.g., quantitative (measurements), qualitative (observations)) • Measurement (e.g., inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures) • Characteristics of results (e.g., empirical, tentative, testable, falsifiable, self-correcting)
Scientific explanations
• Types (e.g., hypothesis, theory, model, law) • Formation (e.g., existing knowledge and new evidence, creativity and imagination, logic) • Rules (e.g., logically consistent, based on evidence, based on historical and current knowledge) • Outcomes (e.g., new knowledge, new methods, new technologies, new investigations)

4.4 Attitudes towards science

Attitudes play a crucial role in increasing the motivation to learn science and technology. Students' attitudes towards science will help them to develop their

knowledge further, and also help them apply the concepts and methods productively to find career and daily life benefits for their entire lives. As a consequence, PISA's 2006 assume that individuals' science competency includes not just only ability in science but also their dispositions toward science which means the inclusion of certain attitudes, beliefs, motivational orientations, self-efficacy, and values (OECD 2007, p. 39).

PISA 2006 assesses the students' attitudes and engagement with science in four following areas: support for scientific enquiry, self-belief as science learners, interest in science, and responsibility towards resources and environments (OECD, 2007, p. 122).

- *Support for scientific enquiry* is considered as an important key area in the attitude assessment regarding to science. It directly reflects the appreciation and value of science from the perspective of students. When it comes to science-related issues, how student involve scientific ways to the processes of collecting evidence, investigating, thinking critically and making a conclusion.
- *Self-belief as a science learners* was selected in the assessment because it is important to study whether the students have their belief toward the ability to study science.
- *Interest in science* is included in the students' assessment because it has formed the relationships between the awareness of the importance of science, the willingness to learn and practice science, and their

consideration to work related to science (see, for example, Osborne et al., 2003).

- *Responsibility towards resources and environments* has become an international issue, especially environmental concern. The assessment include the responsibility that student should have toward environmental sustainability (see, for example, Rickinson, 2001).

Table 8. PISA 2006 areas for assessment of attitudes toward science (OECD, 2007, p. 123)

Support for scientific enquiry
Students who support scientific enquiry: • Acknowledge the importance of considering different scientific perspectives and arguments. • Support the use of factual information and rational explanations. • Express the need for logical and careful processes in drawing conclusions.
Measures include: questions on support for scientific enquiry (integrated into the science assessment); general value of science; personal value of science.
Self-belief as science learners
Students with Self-belief as science learners believe they can: • Handle scientific tasks effectively. • Overcome difficulties to solve scientific problems. • Demonstrate strong scientific abilities.
Measures include: questions on self-efficacy in science; self-concept in science.

Table 8. (Cont.)

Interest in science
Students with interest in science: • Indicate curiosity in science and science-related issues and endeavors. • Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods. • Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science-related careers.
Measures include: questions on interest in learning science topics (integrated into the science assessment); general interest in science; enjoyment of science; importance of learning science; instrumental motivation to learn science; future-oriented motivation to learn science; expectations for a science-related career at age 30; participation in science-related activities.
Responsibility towards resources and environments
Students with responsibility towards resources and environments: • Show a sense of personal responsibility for maintaining a sustainable environment. • Demonstrate awareness of the environmental consequences of individual actions. • Demonstrate willingness to take action to maintain natural resources.
Measures include: questions on awareness of environmental issues; level of concern for environmental issues; optimism for the evolution of selected environmental issues; and responsibility for sustainable development.

The framework of PISA emphasizes that learners' confidence in their ability in science does not ensure they are successful, but it is important to believe that it is possible to overcome difficulties when they invest in learning. This means, they must have a strong sense of self-efficacy (Bandura, 1986, 1993). This important attitude will help learners to be able to overcome problems and obstacles throughout their entire lives. In contrast, those who have low or do not have this

confidence in their abilities to what they judge to be important to overcome problems may find it difficult to get succeed. As Bandura puts it:

“among the mechanisms of agency, none is more central or pervasive than people’s beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives. Efficacy beliefs influence how people feel, think, motivate themselves and behave” (Bandura, 1993, p. 118).

The impact that of self-efficacy has on motivation is outlined on the study made for PISA. In this work, the ability of learners to keep pushing their boundaries and the impact this has on learning, is outlined. Moreover, self-efficacy is compared with the kind of confidence that is needed for learners to successfully master specific learning tasks, and it goes beyond how good they think they are in the subject, for example, science (OECD 2007, p. 134).

Gender differences on the index of self-efficacy in science had not been found in the majority of countries. In 2003, PISA results show that there were gender differences in self-efficacy in mathematics, with the higher level of self-efficacy among males. PISA 2006 shows the same results but only in five countries, namely, Japan, Netherlands, Iceland, Korea, and Chinese Taipei (OECD 2007, p. 134). Besides, within the participating countries, all results about student self-efficacy in relation to science performance have been positively reported

(OECD 2007, p. 136). This justifies why we will give a particular attention to self-efficacy as a central predictor variable in our own research.

5. Conclusion

This chapter has discussed critically the meaning and the importance of scientific literacy. Definitions of scientific literacy have been proposed by numerous researchers. Those definitions are slightly different but have mutual linkages between each other, tending to balance knowledge about science and the capacity to apply scientific knowledge to everyday life. However, there is no definite meaning of scientific literacy and it is still controversial among researchers. Nevertheless, scientific literacy has been used widely in science education since the past until today. And, the fact that scientific literacy was included in PISA as one of the core dimensions of student assessment gave a new impetus to the field. However, as we discussed in this chapter, PISA also includes a particular definition of scientific literacy, and operationalizes the concept, as we will continue to see in the following chapter, in specific ways.

The next chapter will focus on research methodology, describing the sample and the data gathered from PISA 2006, which mainly assessed students' scientific literacy, in two European and two Asian countries.

CHAPTER III

RESEARCH DESIGNS AND METHODOLOGY

This study is a cross-cultural study between two European (Portugal and Belgium) and two Asian countries (Thailand and Korea), performing a secondary analysis to explore the predictors of attitudes and knowledge in science. In this chapter we will consider the research questions and objectives, the research instruments, population and sample, data collection procedures and data analysis.

1. Research Questions and Objectives

This study aims to explore how different cultural and geographic contexts can influence the predictors of students' performance, particularly in what regards young people attitudes and knowledge about science. The research questions include:

1. What are the predictors of students' attitudes and knowledge in PISA 2006?
2. Are there differences between the predictors of attitudes and knowledge between European and Asian students?
3. Does the country's diverse profile in terms of PISA results ("high achievers" vs. "low achievers"), moderate the influence of the predictors?

In general, the objectives of this study are:

1. To investigate the predictors of attitudes and knowledge of students in PISA 2006 between two European and two Asian countries.
2. To compare the predictors of attitudes and knowledge of students in PISA 2006 between two European and two Asian countries, namely Portugal and Belgium, and Thailand and Korea.

2. Research instruments

The Programme for International Student Assessment (PISA) is a triennial survey of the knowledge and skills of 15-year-old students. It is the product of collaboration between participating countries and economies through the Organization for Economic Cooperation and Development (OECD), and draws on leading international expertise to develop valid comparisons across countries and cultures. More than 400,000 students from 57 countries, including 30 OECD member countries and 27 non-OECD countries, making up close to 90% of the world economy took part in PISA 2006. As mentioned before, the focus was on science but the assessment also included reading and mathematics and collected data on student, family and institutional factors that could help explain differences in performance.

The purpose of the PISA 2006 study was to assess both the cognitive and affective aspects of students' *scientific literacy*. The cognitive aspects include students' knowledge and their capacity to use this knowledge effectively, as they carry out certain cognitive processes that are characteristic of science and scientific

enquiries of personal, social, or global relevance. In assessing scientific competencies, PISA is concerned with issues to which scientific knowledge can contribute and which will involve students, either now or in the future, in making decisions. From the point of view of their scientific competencies, students respond to such issues in terms of their understanding of relevant scientific knowledge, their ability to access and evaluate information, their ability to interpret evidence bearing on the issue and their ability to identify the scientific and technological aspects of the issue (Koballa et al, 1997; Law, 2002). PISA also assesses non-cognitive aspects: how students respond affectively. Attitudinal aspects of their response engage their interests, sustain their supports, and motivate them to take actions (Schibeci, 1984).

PISA's assessment does not focus on the knowledge that students are learning in the classroom today. Instead, it wants to explore how good those young people have the potential to bring knowledge and skills they have learnt to apply in real life. That is the reason why PISA does not do its assessment by using school curriculum. PISA emphasizes the knowledge and skills needed in the real world outside the school in the future in both studies in higher levels, in their careers and their personal lives. PISA called this "*Literacy*," and the assessment may be summarized briefly as *the measures for the future*. With these goals, PISA does not study students in the one specific class but using a group sample of 15-years-old students, which is considered the age that they complete compulsory education.

Evaluation of PISA is designed to create indicators of education management result that education system of one country provides to the youth, mainly the knowledge and skills in the areas of reading literacy, mathematics literacy and scientific literacy. At the time when young people graduated or completed their compulsory education, in addition to academic knowledge and skills of young people, PISA also collects information about the background of students and schools in order to interpret the results. This is to be interpreted the findings in the broader context of teaching and learning. So, data from the PISA assessment is beneficial to academic management for researchers and all areas that related to education to look for the weaknesses and strengths as well as factors that contribute to it.

Since the purpose of PISA is to indicate the tendency for changes in the educational results of participating countries, PISA makes an assessment every three years although the focus in each time is different (see Table 9). The assessment is done according to the cycle. The first cycle began since PISA 2000 until it was complete in PISA 2006. The second cycle began in 2009 with the project entitled “*PISA 2009*” which is the latest assessment. Therefore, the focus is on reading literacy like PISA 2000 in the first cycle. To assess knowledge and skills which PISA calls “*literacy*”, the weight of measurement varies according to the aspect. PISA 2000 puts an emphasis on reading literacy, PISA 2003 on mathematics literacy and PISA 2006 on scientific literacy.

Since PISA 2009 is the first assessment in the second cycle. Therefore, the weight is on reading literacy to indicate the trends of the results assessed from the first cycle

Table 9. The cycles of assessment of PISA

Years	First cycle			Second cycle		
	PISA 2000	PISA 2003	PISA 2006	PISA 2009	PISA 2012	PISA 2015
Main	Reading	Mathematics	Science	Reading	Mathematics	Science
Minor	Mathematics	Science	Reading	Mathematics	Science	Reading
	Science	Reading	Mathematics	Science	Reading	Mathematics

Characteristics of Assessment Tool for Scientific Competencies

The assessment of competencies in PISA 2006 can be done in many ways such as asking students to choose a reasonable conclusion based on the given evidence or data, asking students to give reasons to support or disagree with the conclusion derived from a certain procedure, asking students to explain or give reasons as to what conclusion a particular procedure should lead to, or asking students to criticize whether the specified assumption for such study which leads to a particular conclusion is appropriate or not (see Table 10).

Table 10. Tests used in PISA 2006 according to scientific competencies and characteristics of the test

Scientific Competencies	Multiple Choice (items)	Complex multiple - choice (items)	Open-constructed response (items)	Closed-constructed response (items)	Total (items)
Identifying Scientific Issues: (ISI)	9	10	5	-	24
Explain Phenomena Scientifically: (EPS)	22	11	16	4	53
Using Scientific Evidence: (USE)	7	8	15	1	31
Total	38	29	36	5	108

Methods of Assessment

The assessment in PISA heavily depends on the development of reliable instruments with a determined structure and a procedure for data collection that follows very specific requirements, as follows:

- “The test contains both multiple-choice questions and open-ended forms. Almost all units in the test contain the stories written out of the scenarios which students must encounter in real life.
- The whole test needs to be done within 6 hours and a half (390 minutes). The science test is intended for approximately 4 hours and a half whereas the mathematics and reading tests are for 1 hour each. However, to do a test for 6 hours is impossible. Therefore, PISA

designs many versions of the test, each of which contains a mixture of various test questions with the same weight. Students get different versions of the test and each person spend approximately 2 hours on the test.

- Apart from the test, students need to fill out the questionnaire for the survey on their background, their learning habit as well as their learning environment, their attachment to the school and their learning motivation.
- The school headmaster must fill out the questionnaire on the school characteristics which include specific information, environment and elements of the school such teacher qualification and learning and teaching environments” (OECD, 2006, p. 8, OECD, 2007, p. 22).

Competency areas

Scientific literacy

In a world shaped by science and technology, everybody needs to have a basic understanding of scientific concepts and procedures. In particular, students should be able to appropriately apply the knowledge obtained according to specific situations. The PISA questions on science, survey important concepts from physics, chemistry, biology and the earth sciences. These concepts are not simply tested, rather they must be applied to realistic scientific problems.

A Sample of PISA Science questions: (Source: *Assessing Scientific, Reading and Mathematical Literacy – A Framework for PISA 2006*, OECD, 2006)

Example 1: Ultrasound (p. 149)

In many countries, images can be taken of a foetus (developing baby) by ultrasound imaging (echnography). Ultrasounds are considered safe for both the mother and the foetus.



The doctor holds a probe and moves it across the mother's abdomen. Ultrasound waves are transmitted into the abdomen. Inside the abdomen they are reflected from the surface of the foetus. These reflected waves are picked up again by the probe and relayed to a machine that can produce an image.

Question 1.1: ULTRASOUND (Item type: Open – constructed response)

*To form an image the ultrasound machine needs to calculate the **distance** between the foetus and the probe.*

The ultrasound waves move through the abdomen at a speed of 1540 m/s.

What measurement must the machine make so that it can calculate the distance?

.....

.....

ULTRASOUND SCORING: Question 1.1

Full credit

Code 1: It must measure the time the ultrasound wave takes to travel from the probe to the surface of the foetus and reflect back.

- *The time of travel of the wave.*
- *The time.*
- *Time. Distance = speed / time. [Note: Although the formula is incorrect, the student has correctly identified “time” as the missing variable.]*
- *It must find when the ultrasound finds the baby.*

No credit

Code 0: Other responses.

- *The distance.*

Code 9: Missing.

Question 1.2: ULTRASOUND (Item type: Attitudinal) (p. 151).

How much interest do you have in the following information?

Tick only one box in each row.

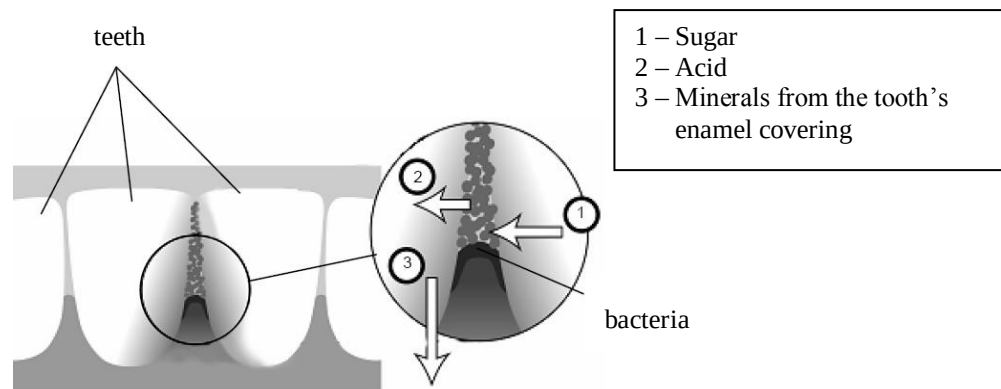
	<i>High Interest</i>	<i>Medium Interest</i>	<i>Low Interest</i>	<i>No Interest</i>
<i>a) Understanding how ultrasound can penetrate your body without harming it</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄
<i>b) Learning more about the differences between X-rays and ultrasound</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄
<i>c) Knowing about other medical uses of ultrasound</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄

Example 2: Tooth Decay (p. 127)

Bacteria that live in our mouths cause dental caries (tooth decay). Caries has been a problem since the 1700s when sugar became available from the expanding sugar cane industry.

Today, we know a lot about caries. For example:

- *Bacteria that cause caries feed on sugar.*
- *The sugar is transformed to acid.*
- *Acid damages the surface of teeth.*
- *Brushing teeth helps to prevent caries.*



Question 2.1: TOOTH DECAY (Item type: Multiple choice)

What is the role of bacteria in dental caries?

- A) *Bacteria produce enamel.*
- B) *Bacteria produce sugar.*
- C) *Bacteria produce minerals.*
- D) *Bacteria produce acid.*

TOOTH DECAY SCORING: Question 2.1

Full credit

Code 1: *D. Bacteria produce acid.*

No credit

Code 0: *Other responses.*

Code 9: *Missing.*

Question 2.2: TOOTH DECAY (Item type: Attitudinal) (p. 130)

How much interest do you have in the following information?

Tick only one box in each row.

	<i>High Interest</i>	<i>Medium Interest</i>	<i>Low Interest</i>	<i>No Interest</i>
<i>a) Knowing what tooth decay bacteria</i>				
<i>look like under a microscope</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄
<i>b) Learning about the development of</i>				
<i>a vaccine to prevent tooth decay</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄
<i>c) Understanding how sugar-free foods</i>				
<i>can cause tooth decay</i>	☐ ₁	☐ ₂	☐ ₃	☐ ₄

Mathematical literacy

PISA sees mathematics as an important tool for understanding and tackling the demands of life. The basic understanding of mathematics and its importance in our cultural and technological world are therefore necessary. The PISA tests require the students to apply their mathematical knowledge. The application situations range from private and school areas to simple scientific questions and issues.

Mathematics Example²:

Example 1: Building Blocks (p. 46)

Susan likes to build blocks from small cubes like the one shown in the following diagram:



Small cube

Susan has lots of small cubes like this one. She uses glue to join cubes together to make other blocks.

First, Susan glues eight of the cubes together to make the block shown in Diagram A:

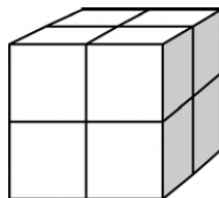


Diagram A

² PISA RELEASED ITEMS -MATHEMATICS; <http://www.oecd.org/pisa/38709418.pdf>

Then Susan makes the solid blocks shown in Diagram B and Diagram C below:

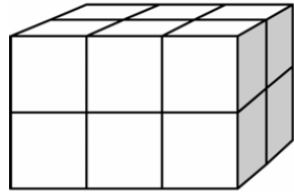


Diagram B

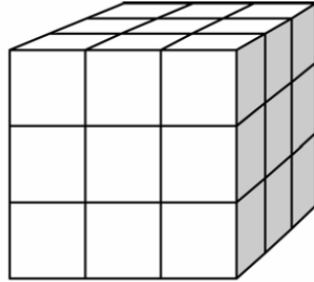


Diagram C

Question 1.1: BUILDING BLOCKS

How many small cubes will Susan need to make the block shown in Diagram B?

Answer: cubes.

BUILDING BLOCKS SCORING: Question 1.1

Full credit

Code 1: 12 cubes.

No credit

Code 0: Other responses.

Code 9: Missing.

Question 1.2: BUILDING BLOCKS

How many small cubes will Susan need to make the solid block shown in Diagram C?

Answer: cubes.

BUILDING BLOCKS SCORING: Question 1.2

Full credit

Code 1: 27 cubes.

No credit

Code 0: Other responses.

Code 9: Missing.

Reading literacy

Reading literacy means more than being able to extract information from texts. In particular, PISA examines the ability to understand the content, intent and form of different types of written texts and to be able to fit them into a larger context. Reading literacy is seen as a necessary requirement for successful participation in society and life.

Reading Example: BEES³

Bees Text (p. 84)

The information on this page and the next page is from a booklet about bees.

Refer to the information to answer the questions which follow it.

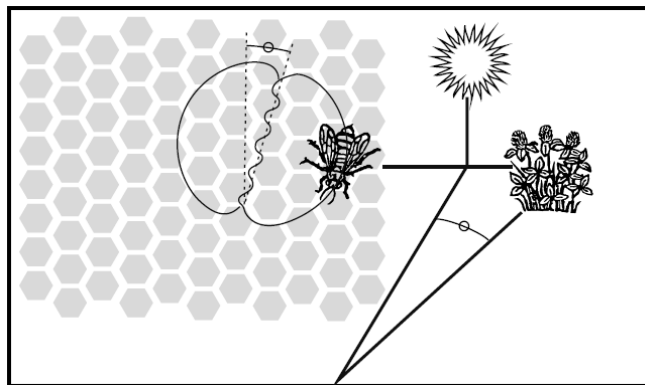
COLLECTING NECTAR

Bees make honey to survive. It is their only essential food. If there are 60,000 bees in a hive about one third of them will be involved in gathering nectar which is then made into honey by the house bees. A small number of bees work as

³ PISA RELEASED ITEMS –READING; <http://www.oecd.org/pisa/38709396.pdf>

foragers or searchers. They find a source of nectar, then return to the hive to tell the other bees where it is.

Foragers let the other bees know where the source of the nectar is by performing a dance which gives information about the direction and the distance the bees will need to fly. During this dance the bee shakes her abdomen from side to side while running in circles in the shape of a figure 8. The dance follows the pattern shown on the following diagram.



The diagram shows a bee dancing inside the hive on the vertical face of the honeycomb. If the middle part of the figure 8 points straight up it means that bees can find the food if they fly straight towards the sun. If the middle part of the figure 8 points to the right, the food is to the right of the sun.

The distance of the food from the hive is indicated by the length of time that the bee shakes her abdomen. If the food is quite near the bee shakes her abdomen for a short time. If it is a long way away she shakes her abdomen for a long time.

MAKING HONEY

When the bees arrive at the hive carrying nectar they give this to the house bees. The house bees move the nectar around with their mandibles, exposing it to the

warm dry air of the hive. When it is first gathered the nectar contains sugar and minerals mixed with about 80% water. After ten to twenty minutes, when much of the excess water has evaporated, the house bees put the nectar in a cell in the honeycomb where evaporation continues. After three days, the honey in the cells contains about 20% water. At this stage, the bees cover the cells with lids which they make out of beeswax.

At any one time the bees in a hive usually gather nectar from the same type of blossom and from the same area. Some of the main sources of nectar are fruit trees, clover and flowering trees.

GLOSSARY

house bee a worker bee which works inside the hive.

mandible mouth-part.

Question 1.1: BEES

What is the purpose of the bees' dance?

- A) To celebrate the successful production of honey.
- B) To indicate the type of plant the foragers have found.
- C) To celebrate the birth of a new Queen Bee.
- D) To indicate where the foragers have found food.

BEES SCORING: Question 1.1

QUESTION INTENT: Forming a Broad Understanding: understanding the main idea of a self-contained section of a text

Full credit

Code 1: To indicate where the foragers have found food.

No credit

Code 0: Other responses.

Code 9: Missing.

Question 1.2: BEES

Write down three of the main sources of nectar.

- 1)
- 2)
- 3)

BEES SCORING: Question 1.2

QUESTION INTENT: Retrieving Information: literal match, no distracting information, Base codes on the following responses:

- a: fruit trees*
- b: clover*
- c: flowering trees*
- d: trees*
- e: flowers*

Full credit

Code 1: (in any order) abc, abe, bde

No credit

Code 0: Other responses. combinations of a,b,c,d and e, or other answers.

- *fruit*

Code 8: Off task.

Code 9: Missing.

Information about the test questions

The focus of PISA 2006 is on the survey of scientific literacy. About half of the test items are therefore concerned with scientific problems from the areas of physics, chemistry, biology and the earth sciences. A quarter of the test items come from the area of reading and a quarter from the area of mathematics.

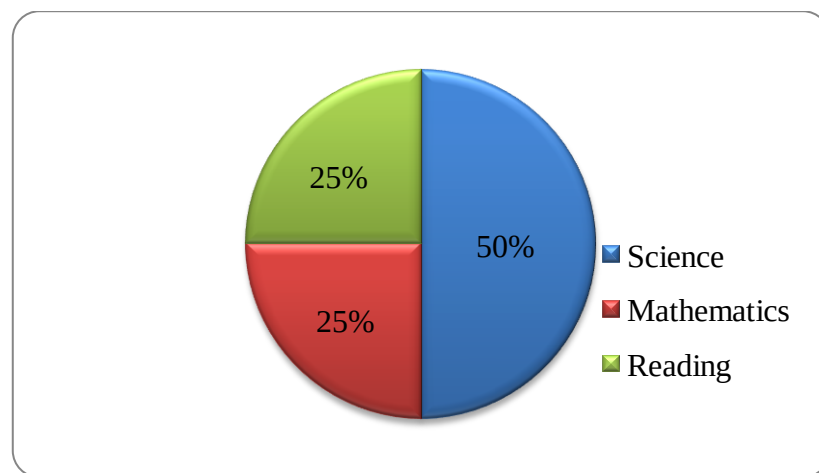


Figure 4. Distribution of items in PISA 2006

A new feature in PISA 2006 is the survey of so-called motivational attitudes and orientations. After working on various tests, the students are asked about the extent to which they see the scientific area addressed as being important, for them personally, or as being interesting.

Questionnaires:

Students' questionnaire

The conditions under which students grow up, live and learn influence their learning within and outside of school. For this reason, PISA also collects information on the social background of the students. This information is necessary in order to be able to conduct fair national and international comparisons of students' competencies. With the help of the students' questionnaire, social background characteristics are surveyed.

Example: Student questionnaire⁴:

Section 1: ABOUT STUDENT (p. 3)

1) *What <grade> are you in?*

<grade>

2) *On what date were you born?*

(Please write the day, month and year you were born)

____ - ____ - 19____
Day Month Year

3) *Are you female or male?*

Female Male

☐₁ ☐₂

⁴ http://pisa2006.acer.edu.au/downloads/PISA06_Student_questionnaire.pdf

Section 2: FAMILY AND HOME (p. 5)

1) What is the <highest level of schooling> completed by your mother?

If you are not sure which box to choose, please ask the

<test administrator> for help.

(Please tick only one box)

<ISCED level 3A> 1 ☐ ₁

<ISCED level 3B, 3C> 2 ☐ ₂

<ISCED level 2> 3 ☐ ₃

<ISCED level 1> 4 ☐ ₄

She did not complete <ISCED level 1> 5 ☐ ₅

2) Does your mother have any of the following qualifications?

If you are not sure how to answer this question, please ask the

<test administrator> for help.

(Please tick one box in each row)

	Yes	No
a) <ISCED level 5A, 6>	☐ ₁	☐ ₂

b) <ISCED level 5B>	☐ ₁	☐ ₂
---------------------	---------------------------------------	---------------------------------------

c) <ISCED level 4>	☐ ₁	☐ ₂
--------------------	---------------------------------------	---------------------------------------

3) How many books are there in your home? (p. 10)

There are usually about 40 books per meter of shelving. Do not include magazines, newspapers, or your schoolbooks.

(Please tick only one box)

- | | |
|---------------------|---------------------------------------|
| 0-10 books | ☐ ₁ |
| 11-25 books | ☐ ₂ |
| 26-100 books | ☐ ₃ |
| 101-200 books | ☐ ₄ |
| 201-500 books | ☐ ₅ |
| More than 500 books | ☐ ₆ |

School questionnaire

Characteristics of the school, along with school and lesson organization, also have an effect on the performance of students. In the school questionnaire, the school principal is requested to give details about the general conditions in the school (size etc.) and the resources available (teachers, computer equipment etc.).

Example: School questionnaire⁵:

Section: THE STRUCTURE AND ORGANISATION OF THE SCHOOL

(p. 3)

- 1) *As at <February 1, 2006>, what was the total school enrolment
(number of students)?*

(Please write a number in each line. Write 0 (zero) if there are none)

a) Number of boys: _____

b) Number of girls: _____

- 2) *Is your school a public or a private school?*

(Please tick only one box)

A public school ☐ ₁

(This is a school managed directly or indirectly by a public education authority, government agency, or governing board appointed by government or elected by public franchise.)

A private school ☐ ₂

(This is a school managed directly or indirectly by a non-government organization; e.g. a church, trade union, business, or other private institution.)

⁵ http://pisa2006.acer.edu.au/downloads/PISA06_School_questionnaire.pdf

Parents' questionnaire

The parents' survey should provide information about the importance given to science for the students' future career or apprenticeship. Further questions concern the parents' estimation of the school.

Example: Parent questionnaire⁶:(p. 6-7)

Section: SCIENCE IN YOUR CHILD'S CAREER AND THE JOB MARKET

- 1) We are interested in what you think about the need for science skills in the job market today.

How much do you agree with the following statements?

(Please tick only one box in each row.)

	<i>Strongly Agree</i>	<i>Agree</i>	<i>Disagree</i>	<i>Strongly Disagree</i>
a) It is important to have good scientific knowledge and skills in order to get any good job in today's world	☐ ₁	☐ ₂	☐ ₃	☐ ₄
b) Employers generally appreciate strong scientific knowledge and skills among their employees	☐ ₁	☐ ₂	☐ ₃	☐ ₄
c) Most jobs today require some scientific knowledge and skills	☐ ₁	☐ ₂	☐ ₃	☐ ₄
d) It is an advantage in the job market to have good scientific knowledge and skills	☐ ₁	☐ ₂	☐ ₃	☐ ₄

⁶ http://pisa2006.acer.edu.au/downloads/PISA06_Parent_questionnaire.pdf

2) The following questions refer to **<science-related careers>**. A <science-related career> is one that requires studying science at tertiary level (e.g. university). So, careers like engineer (involving physics), weather forecaster (involving Earth science), optician (involving biology and physics), and medical doctors (involving the medical sciences) are all examples of <science-related careers>.

Please answer the questions below.

(Please tick only one box in each row.)

	Yes	No
a) Does anybody in your family (including you) work in a <science - related career>?	☐ ₁	☐ ₂
b) Does your child show an interest in working in a <science - related career>?	☐ ₁	☐ ₂
c) Do you expect your child will go into a <science-related career>?	☐ ₁	☐ ₂
d) Has your child shown interest in studying science after completing <secondary school>?	☐ ₁	☐ ₂
e) Do you expect your child will study science after completing <secondary school>?	☐ ₁	☐ ₂

3. Population and Sample

PISA defined their population with reference to a target age because grades could not be defined as internationally comparable. PISA covers students who are aged between 15 years 3 months and 16 years 2 months at the time of the assessment and who have completed at least 6 years of formal schooling, regardless of the type of institution in which they are enrolled and of whether they are in full-time or part-time education (PISA 2006: Science Competencies for Tomorrow's World, Vol.1, OECD 2007, p. 22).

The sampling procedure is carried out in the participating countries according to detailed specifications from the international project management. First of all, the schools were chosen in a random sampling process. Students are then chosen within the schools also using a random selection.

There are a variety of test items in the PISA study. Each school names a so-called school coordinator who is the contact person for both students and parents and is responsible for preparing the implementation of the test.

The tests are carried out by trained test administrators. In the majority of schools, there will only be one day of testing. In some schools, there will be two days of testing. The time required to sit the test on both days of testing is about three school periods.

Questionnaires must be completed in all schools during the testing time. Furthermore, the students will receive questionnaires for their parents.

4. Data Collection

The data used for this study are from the 2006 Programme for International Student Assessment (PISA), a database that focuses on students' competencies in science, but also includes, as we saw, items on reading and mathematics and collected data on student, family and institutional factors that could explain differences in performance. In this cross-cultural study we used data from two European and two Asian countries that differ regarding their level of PISA 2006 results – “high-achievers” (Belgium and Korea) and “low-achievers” (Portugal and Thailand) – to investigate and compare the predictors of attitudes and knowledge of students in science.

4.1 Data preparing

Primary data was downloaded from database of the PISA 2006 International Database website; <http://www.oecd.org/pisa/>; (<http://pisa2006.acer.edu.au/downloads.php>). Then we transformed the data from original files to SPSS format and created a new database. We then selected data only from two European (Portugal N = 5,109 and Belgium N = 8,857) and two Asian countries (Thailand N = 6,192 and Korea N = 5,176). Finally, we computed the scores for science knowledge and attitudes.

Science knowledge score was calculated by performing the average of total science scores. In what concerns science attitudes we decided to use only scores from two sub-scales: interest in science and support for scientific enquiry. As we mentioned in the previous chapter, we wanted to deepen our understanding of the

role of science self-efficacy as a predictor variable – and therefore we limited the science attitudes to interest in science and support for scientific enquiry.

4.2 Descriptive Statistics Analysis

We started by performing descriptive statistics analysis for each sample of the four countries (Belgium, Portugal, Korea, and Thailand) such as gender, grade, level of education, and books at home.

Table 11 presents the results of descriptive statistics in terms of participants' gender. The distribution of gender is balanced in all the countries even if there are slightly more males in Belgium and Korea and slightly more females in Portugal and Thailand.

Table 11. Distribution of frequency by gender

	Belgium		Portugal		Korea		Thailand	
	<i>(N = 8,857)</i>		<i>(N = 5,109)</i>		<i>(N = 5,176)</i>		<i>(N = 6,192)</i>	
	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>
<u>Gender</u>								
Female	4,231	47.77	2,684	52.53	2,563	49.52	3,584	57.88
Male	4,626	52.23	2,425	47.47	2,613	50.48	2,608	42.12
Total	8,857	100.00	5,109	100.00	5,176	100.00	6,192	100.00

Table 12 presents the results of descriptive statistics in terms of participants' grade. In all countries, the majority of students are in grade 10; in Korea the percentage is very high, probably a consequence of the banning of grade retention in the country

Table 12. Distribution of frequency by grade

	Belgium		Portugal		Korea		Thailand	
	<i>(N = 8,857)</i>		<i>(N = 5,109)</i>		<i>(N = 5,176)</i>		<i>(N = 6,192)</i>	
	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>
<u>Grade</u>								
7	31	0.35	286	5.60	-	-	1	0.02
8	361	4.08	585	11.45	-	-	72	1.16
9	2,581	29.14	1,405	27.50	56	1.08	1,962	31.69
10	5,796	65.44	2,725	53.34	5,083	98.20	3,954	63.86
11	87	0.98	12	0.23	37	0.71	203	3.28
missing	1	0.01	96	1.88	-	-	-	-
Total	8,857	100.00	5,109	100.00	5,176	100.00	6,192	100.00

Table 13 presents the results of descriptive statistics in terms of educational level of mother. In Belgium the highest percent is 30.68% of Upper secondary education (ISCED 3A) and Post-secondary non-tertiary education (ISCED 4), the second is 24.79% of Vocational tertiary education (ISCED 5B), the third is 19.21% of Theoretically oriented tertiary and Post-graduate (ISCED 5A, 6). In Portugal the

highest percent is 28.13% of None or not completed⁷, the second is 18.14% of Upper secondary education (ISCED 3A), Post-secondary non-tertiary education (ISCED 4), the third is 16.91% of Primary education (ISCED 1).

In Korea, the highest percent is 43.62% of Upper secondary education (ISCED 3A) and Post secondary non-tertiary education (ISCED 4), the second is 20.17% of Theoretically oriented tertiary and Post-graduate (ISCED 5A, 6), the third is 14.30% of Vocational/ Pre-vocational Upper secondary education (ISCED 3B, C). In Thailand the highest percent is 47.27% of Primary education (ISCED 1), the second is 14.57% of Upper secondary education (ISCED 3A) and Post-secondary non-tertiary education (ISCED 4), the third is 12.77% of Theoretically oriented tertiary and Post-graduate (ISCED 5A, 6).

Table 13 Distribution of Educational level of mother (ISCED)

	Belgium (<i>N</i> = 8,857)		Portugal (<i>N</i> = 5,109)		Korea (<i>N</i> = 5,176)		Thailand (<i>N</i> = 6,192)	
	<i>Frequency</i>	(%)	<i>Frequency</i>	(%)	<i>Frequency</i>	(%)	<i>Frequency</i>	(%)
<u>Educational level of mother</u>								
None or not completed	273	3.08	1,437	28.13	80	1.55	577	9.32
ISCED 1	257	2.90	864	16.91	197	3.81	2,927	47.27
ISCED 2	621	7.01	783	15.33	571	11.03	783	12.65
ISCED 3B,C	623	7.03	79	1.55	740	14.30	169	2.73
ISCED 3A, ISCED 4	2,717	30.68	927	18.14	2,258	43.62	902	14.57
ISCED 5B	2,196	24.79	190	3.72	215	4.15	-	-
ISCED 5A, 6	1,701	19.21	731	14.31	1,044	20.17	791	12.77
missing	469	5.30	98	1.92	71	1.37	43	0.69
Total	8,857	100.00	5,109	100.00	5,176	100.00	6,192	100.00

⁷ ISCED1 for Portugal is grade 6 but many of the parents of the Portuguese students did not complete grade 6 (probably only grade 4)

Table 14 presents the results of descriptive statistics in terms of educational level of father. In Belgium the highest percent is 31.27% of Upper secondary education (ISCED 3A) and Post-secondary non-tertiary education (ISCED 4), the second is 24.18% of Theoretically oriented tertiary and Post-graduate (ISCED 5A, 6), the third is 17.20% of Vocational tertiary education (ISCED 5B). In Portugal, the education level of the father is similar to that of the mother.

In Korea, the highest percent is 33.83% of Theoretically oriented tertiary and Post-graduate (ISCED 5A, 6), the second is 30.39% of Upper secondary education (ISCED 3A) and Post secondary non-tertiary education (ISCED 4), the third is 15.51% of Vocational/ Pre-Vocational Upper secondary education (ISCED 3B, C). In Thailand, the education level of the father is similar to that of the mother.

Table 14. Distribution of Educational level of father (ISCED)

	Belgium		Portugal		Korea		Thailand	
	<i>(N = 8,857)</i>		<i>(N = 5,109)</i>		<i>(N = 5,176)</i>		<i>(N = 6,192)</i>	
	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>
<u>Educational level of father</u>								
None or not completed	259	2.92	1,492	29.20	78	1.51	467	7.54
ISCED 1	275	3.10	849	16.62	161	3.11	2,566	41.44
ISCED 2	614	6.93	711	13.92	431	8.33	853	13.78
ISCED 3B,C	549	6.20	123	2.41	803	15.51	225	3.63
ISCED 3A, ISCED 4	2,770	31.27	909	17.79	1,573	30.39	1,079	17.43
ISCED 5B	1,523	17.20	172	3.37	275	5.31	-	-
ISCED 5A, 6	2,142	24.18	643	12.59	1,751	33.83	872	14.08
missing	725	8.19	210	4.11	104	2.01	130	2.10
Total	8,857	100.00	5,109	100.00	5,176	100.00	6,192	100.00

Table 15 presents the results of descriptive statistics in terms of number of books at home. In European countries, In Belgium the highest percent is 30.76% of 26-100 books at home, the second is 16.79 % of 101-200 books at home, the third is 15.89 % of 11-25 books at home. In Portugal the highest percent is 31.71% of 26-100 books at home, the second is 21.12% of 11-25 books at home, the third is 16.40% of 0-10 books at home.

In Asian countries, In Korea the highest percent is 33.10% of 26-100 books at home, the second is 24.57% of 101-200 books at home, the third is 19.82% of 201-500 books at home. In Thailand the highest percent is 31.91% of 11-25 books at home, the second is 28.42% of 26-100 books at home, the third is 23.50% of 0-10 books at home.

Table 15. Distribution of how many books at home

	Belgium		Portugal		Korea		Thailand	
	<i>(N = 8,857)</i>		<i>(N = 5,109)</i>		<i>(N = 5,176)</i>		<i>(N = 6,192)</i>	
	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>	<i>Frequency</i>	<i>(%)</i>
<u>How many book at home</u>								
0 – 10 books	1,147	12.95	838	16.40	262	5.06	1,455	23.50
11 – 25 books	1,407	15.89	1,079	21.12	483	9.33	1,976	31.91
26 – 100 books	2,724	30.76	1,620	31.71	1,713	33.10	1,760	28.42
101 – 200 books	1,487	16.79	732	14.33	1,272	24.57	550	8.88
201 – 500 books	1,261	14.24	484	9.47	1,026	19.82	260	4.20
More than 500 books	722	8.15	311	6.09	411	7.94	113	1.82
missing	109	1.23	45	0.88	9	0.17	78	1.26
Total	8,857	100.00	5,109	100.00	5,176	100.00	6,192	100.00

5. Data Analysis

Secondary analysis involves the use of existing data, collected for the purposes of a prior study, in order to pursue a research interest which is distinct from that of the original work (Hinds et al, 1997; Szabo & Strang, 1997). The existing data was considered and re-analyzed to explore the predictors of attitudes and knowledge of students about science, including the different predictors in two European (Portugal and Belgium) and two Asian countries (Thailand and Korea). Data analysis was completed with SPSS for windows version 19.0 and AMOS.

We started by performing descriptive statistics analysis for mean and standard deviation of science knowledge and attitudes in each countries (Belgium, Portugal, Korea, and Thailand), and we considered group difference by using Multivariate analysis of variance (MANOVA), and then explore the correlation between variables. Subsequently, we performed a series of country by country multiple regression analysis to explore the predictors of science knowledge and attitudes of students about science in each country. Finally, we used multiple group analysis to explore the invariance of the measurement model and of the structural model for attitudes and knowledge of students about science predictors in PISA 2006 in four countries (e.g. Belgium, Portugal, Korea, and Thailand) using AMOS. First, the model was adjusted for the four groups by removing the items that did not contributed for the quality of the model. Secondly, the invariance of the model was evaluated in the four groups by comparison of the unconstricted model (with free factorial weights and variances/covariances of the factors) with a constrained

model where the factorial weights and the factorial variance/ covariance of the four groups are fixed. The statistical significance of the difference of the four models was performed with the Chi-square test.

6. Context of the study

This study considered four countries, two countries in Europe (Belgium and Portugal) and two countries in Asia (Korea and Thailand), with diverse historical cultural and educational traditions.

Belgium:

Belgium is located in the Western Europe, bordering with the south of the Netherlands, west of Germany and Luxembourg, and north and east of France. The capital is Brussels. The total number of population in Belgium is approximately 11 million people in 2012⁸. Cultural regions are separated into Flanders and Wallonia. The official languages are French, Dutch and German. The 75% of the country are Roman Catholic⁹.

With the 0.886 Human Development Index (HDI), Belgium is ranked 17 out of 187 countries and above the regional average of 0.873 HDI¹⁰.

⁸ <http://en.wikipedia.org/wiki/Belgium>

⁹ <http://www.infoplease.com/encyclopedia/world/belgium-land-people.html>,
<http://www.kwintessential.co.uk/resources/global-etiquette/belgium-country-profile.html>

¹⁰ <http://hdrstats.undp.org/en/countries/profiles/bel.html>

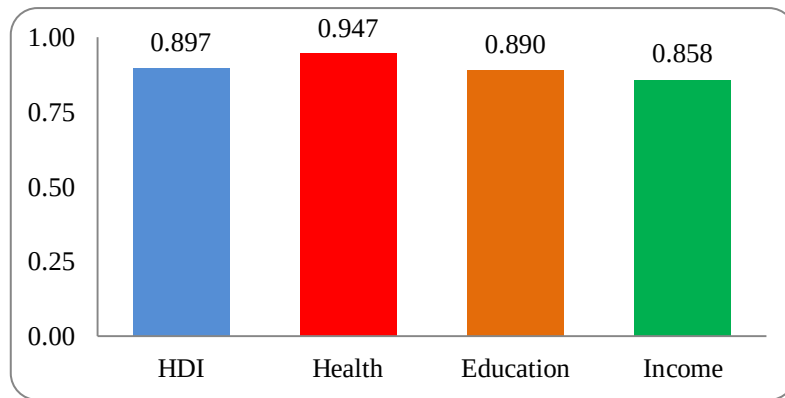


Figure 5. Belgian Human Development Index – Health, Education and Income

Since there are different cultural communities, the culture is, therefore, quite unique. Many Belgians think their culture is the combination of European cultures. The main cultures are 1) Flanders, in the north of Belgium, are originally Dutch, 2) Wallonia – are primarily French and 3) German in the area of the northeast¹¹.

The Educational System in Belgium:

The three educational systems in different communities are as followed:

1) The **Flemish** system consists of nursery and primary education (age 2.5 to 12 years), secondary education (age 12 to 18 years) and tertiary education. There are three two-year consecutive stages in secondary education and, after the first stage, the students have to choose one of the four types of specialization: general, technical, artistic, or vocational education.

¹¹ http://en.wikipedia.org/wiki/Culture_of_Belgium

2) The **French** system consists of nursery school (age 2.5 to 6 years and primary education with the ages of 6 to 12 years), secondary education (age 12 to 18 years and over) and tertiary education. There are three two-year consecutive stages in the 1st type of secondary education: observation (first stage), orientation (second), and determination (third). On the other hand, there are two three-year stages in the 2nd type of secondary education which only 2% of the students are currently enrolled in.

3) The **German** system consists of nursery school (age 3 to 5 or 6 years), primary education (age 6 to 11 years), secondary education (age 12 to 18 years and over), and tertiary education. There are three two-year consecutive stages in secondary education: observation (first stage), orientation (second), and determination (third). During second and third stage, the system offers general, technical and vocational education.

The two main subsystems of higher education in Belgium are university and polytechnic/vocational university (Geyer, 2009).

Portugal:

Portugal is positioned between the North Atlantic Ocean and west of Spain in the South of Western Europe. The number of population in Portugal is

approximately 12.5 million in 2012. The capital and the largest city is Lisbon. Official language is Portuguese¹².

With the 0.809 Human Development Index (HDI), Portugal is ranked 41 out of 187 countries and below the regional average of 0.873 HDI¹³.

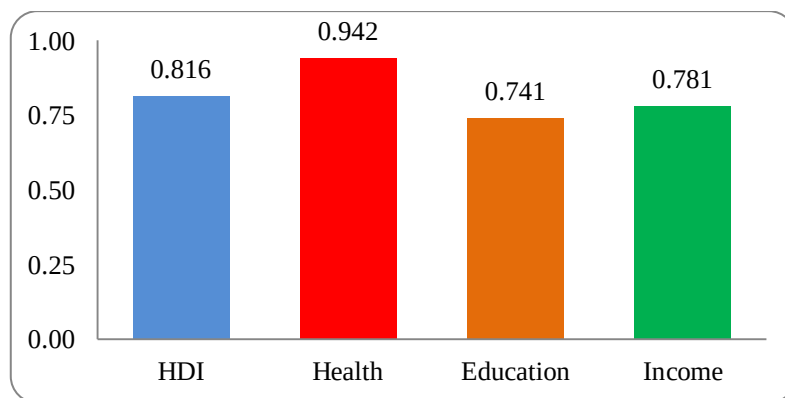


Figure 6. Portuguese Human Development Index – Health, Education and Income

Portuguese culture had been influenced by many civilizations. By observing architectures (such as museums, churches, castles), it has shown that Portugal has a long history with various cultural activities.

The Educational System in Portugal:

The Portuguese educational structure is categorized into three different levels: 1) Nursery and Kindergarten, 2) Primary education with three cycles (1st

¹² <http://en.wikipedia.org/wiki/Portugal>

¹³ <http://hdrstats.undp.org/en/countries/profiles/prt.html>

cycle – four years, rounded education, taught by one teacher with or without assistant, 2nd cycle – two years, various academic disciplines, one teacher per area typically, and 3rd cycle – three years, vocational education, one teacher per subject or multiple subjects), and 3) Secondary education (three years corresponding to 10th through 12th grade, specific studies, preparation for higher education).

Primary education with three cycles is currently mandatory. The two main subsystems of higher education in Portugal are university and polytechnic education¹⁴.

Korea:

South Korea is positioned between the Yellow Sea and Sea of Japan on the southern part of the Korean Peninsula in Eastern Asia. There are over 3,400 islands along 2,413-km coastline of Yellow Sea, South China Sea, and the Sea of Japan. The number of total population in South Korea is approximately 50 million people in 2012, and its capital is Seoul, which is also the largest city of South Korea¹⁵.

With the 0.897 Human Development Index (HDI), South Korea is ranked 15 out of 187 countries and above the regional average of 0.873 HDI¹⁶.

¹⁴ The Ministry of Education, Bureau for European Affairs and International Relations;
http://www.ibe.unesco.org/International/ICE/natrap/Portugal_1.pdf

¹⁵ http://en.wikipedia.org/wiki/South_Korea

¹⁶ <http://hdrstats.undp.org/en/countries/profiles/kor.html>

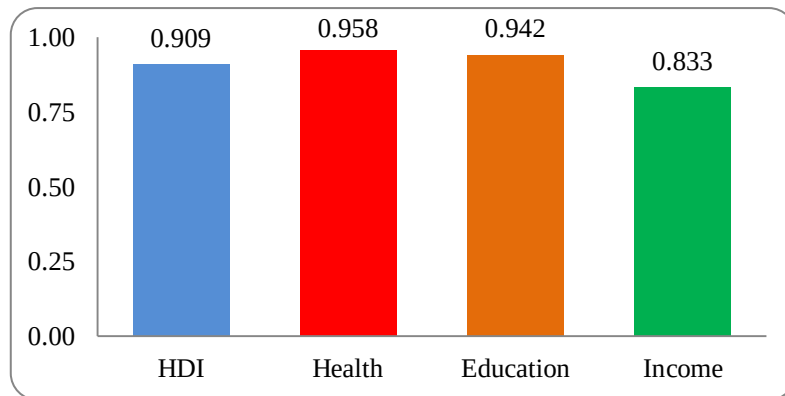


Figure 7. Korean Human Development Index – Health, Education and Income

Regarding to Korean culture, Koreans focus and value harmony with order. They love their families, pay a lot of respect to elders, focus on high education, and work hard for high success. Even though Koreans have strong nationalism, younger generations are influenced by western cultures¹⁷.

The Educational System in Korea:

The South Korean educational structure is organized into four different levels: four years of kindergarten (K1-K4), six years of elementary school (G1-G6), three years of middle school (G7-G9), and three years of high school (G10-G12). Grade 1 through Grade 9 are currently mandatory for every South Korean student. Additionally, there are three different levels of higher education: lower than Bachelor's degree, Bachelor's degree, and Graduate level. The nine subjects

¹⁷ <http://www.ntac.hawaii.edu/downloads/products/briefs/culture/pdf/ACB-Vol2-Iss1-Korea.pdf>

of the core curriculum are as followed: Practical arts, Fine arts, Music, Physical education, Science, Mathematics, Social studies, Korean language, and Moral education. In South Korea, children receive the opportunity to learn English since the third grade in a relaxing environment using conversations rather than grammar, which is still conducted in some middle and high schools¹⁸.

Thailand:

Thailand is located between the Gulf of Thailand and Andaman Sea in Southeast Asia. It is surrounded by Laos in the Northeast, Myanmar in the North and West, Cambodia in the East, and Malaysia in the South. Bangkok, the capital, was founded in 1782 and is the center of modern Western and Thai architecture. The number of total population in Thailand is approximately 67 million people in 2012¹⁹.

With the 0.682 Human Development Index (HDI), Thailand is ranked 103 out of 187 countries and above the regional average of 0.671 HDI²⁰.

¹⁸http://en.wikipedia.org/wiki/Education_in_South_Korea#Ministry_of_Education.2C_Science_and_Technology

¹⁹ <http://en.wikipedia.org/wiki/Thailand>

²⁰<http://hdrstats.undp.org/en/countries/profiles/tha.html>

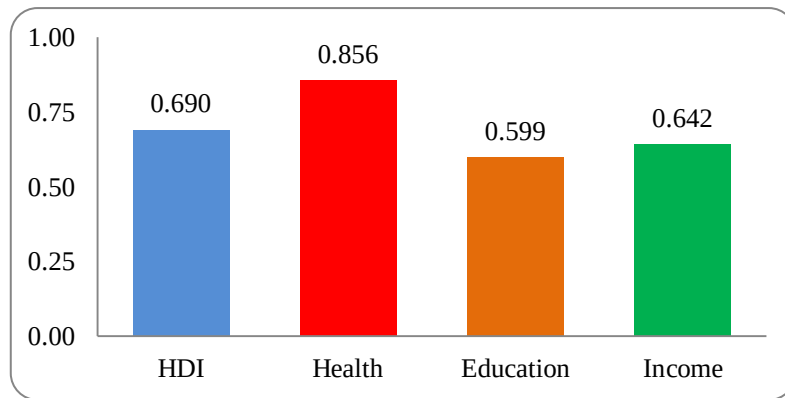


Figure 8. Thai Human Development Index – Health, Education and Income

Since most of the Thai people are Buddhists, they enjoy peaceful and live in a humble way. People pay great respect to the King and monks. Despite the great influence that western culture exerts on Thai nationals, especially at the younger generation, traditional Thai culture is taken as being very important and big efforts are made to preserve traditional Thai culture²¹.

The Educational System in Thailand:

According to Ministry of Education (MOE, 2007), the Thai educational structure is organized into four different levels: three years of pre-elementary, six years of primary education (G1-G6), three years of lower secondary education (G7-G9), and three years of upper secondary education (G10-G12). Grade 1

²¹ <http://www.intrepidtravel.com/de/thailand/culture-geography-history>

through Grade 9 are currently mandatory for every Thai student. Additionally, there are three different levels of higher education: lower than Bachelor's degree, Bachelor's degree, and Graduate level (MOE, 2007).

The over eight subjects of the core curriculum are as followed: Thai language; Mathematics; Science; Social science, Religion and Culture; Health and Physical Education; Art; Career and Technology; and Foreign languages. English is part of the core curriculum for foreign languages and is required at all levels. For pre-primary education focuses on preparing children in terms of their physical, intellectual, emotional/ mental and social readiness (OEC, 2006).

7. Conclusion

International studies such as PISA use a similar instrument to assess students' knowledge and attitudes in spite of differences between countries. The instrument is considered adequate, but surely this diversity should be in our minds when we look at the results.

In our study we considered four countries, two in Europe (Belgium and Portugal) and two in Asia (Korea and Thailand). These countries have diverse cultural traditions and educational systems. However, both Belgium and Korea tend to be well-positioned in international studies of educational achievement, such as PISA, while Portugal and Thailand tend to do less well. In the case of PISA 2006 this profile was similar, with Belgium and Korea as "high achievers" and

Portugal and Thailand as “low achievers”. The combination of cultural diversity and assessment levels is therefore an interesting point of departure to consider predictors of science attitudes and knowledge.

CHAPTER IV

RESULTS

In this chapter we will present the results of the study divided into five parts. We will present the mean and standard deviation of science knowledge and attitudes in the four analyzed countries: Belgium, Portugal, Korea, and Thailand. We will then consider group differences, using multivariate analysis of variance (MANOVA), and explore the correlations between variables. Then, we will perform a series of multiple regression analysis to consider predictors of science knowledge and attitudes among European and Asian countries in each country. Finally, we will present a multiple group analysis to explore the invariance of predictors of science knowledge and attitudes across countries.

1. Descriptive Statistics Analysis

We will present the descriptive of various dimensions for the participating countries (Belgium, Portugal, Korea, and Thailand) such as gender, grade, and books at home will be showed in the table and figure below.

Table 16 presents the mean and standard deviation of science knowledge and attitudes by gender in each country. Regarding science knowledge, the higher means are for both female and male in Korea, followed by Belgium, Portugal and

finally Thailand. In terms of science attitudes, the highest are boys and girls in Thailand, followed by Portugal, Belgium and finally Korea.

Table 16. Mean and Standard Deviation of science knowledge and attitudes by gender for each countries

	Belgium		Portugal		Korea		Thailand	
	<i>(N = 8,857)</i>		<i>(N = 5,109)</i>		<i>(N = 5,176)</i>		<i>(N = 6,192)</i>	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Science Knowledge								
Female	514.51	(90.98)	476.72	(81.64)	523.02	(83.08)	435.67	(74.30)
Male	517.97	(97.99)	481.47	(86.84)	520.84	(90.72)	421.60	(84.85)
Total	516.32	(94.72)	478.97	(84.17)	521.92	(87.02)	429.73	(79.22)
Science Attitudes								
Female	494.26	(70.19)	552.85	(67.70)	484.56	(78.42)	611.29	(77.62)
Male	496.96	(80.04)	556.29	(74.34)	495.78	(85.79)	595.35	(84.62)
Total	495.67	(80.04)	554.48	(70.94)	490.22	(82.41)	604.58	(81.02)

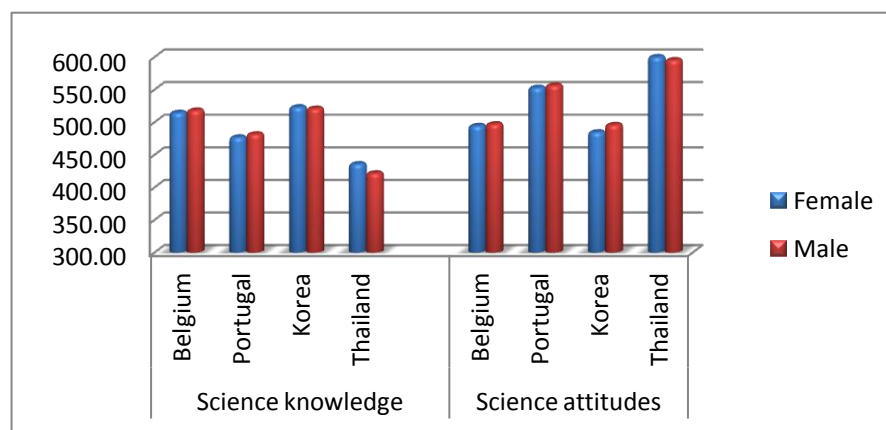


Figure 9. Science knowledge and attitudes by gender in each country

Table 17. Mean and Standard Deviation of science knowledge and attitudes by grade for each country

	Belgium (<i>N</i> = 8,857)		Portugal (<i>N</i> = 5,109)		Korea (<i>N</i> = 5,176)		Thailand (<i>N</i> = 6,192)	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Science Knowledge								
7	341.36	(57.24)	353.81	(53.34)	-		243.51	(-)
8	390.19	(75.03)	399.88	(53.27)	-		342.56	(75.09)
9	454.56	(81.63)	451.64	(62.71)	483.34	(96.99)	390.94	(63.01)
10	551.14	(77.87)	527.06	(63.20)	522.01	(86.86)	447.10	(77.43)
11	616.33	(77.69)	559.75	(79.03)	567.63	(68.36)	498.26	(79.66)
Total	516.34	(94.70)	481.27	(82.95)	521.92	(87.02)	429.73	(79.22)
Science Attitudes								
7	506.43	(77.52)	554.68	(76.79)	-		513.16	(-)
8	501.49	(89.09)	554.36	(76.93)	-		577.47	(78.64)
9	491.28	(78.42)	547.80	(70.02)	494.20	(80.84)	594.08	(83.32)
10	496.62	(72.97)	558.59	(69.02)	490.06	(82.51)	610.24	(79.67)
11	533.71	(78.25)	541.20	(78.06)	506.46	(70.29)	605.90	(73.37)
Total	495.66	(75.50)	554.80	(70.87)	490.22	(82.41)	604.58	(81.02)

Table 17 presents the results of the mean and standard deviation of science knowledge and attitudes by grade in each country. Regarding science knowledge, Korea has the highest mean total, followed by Belgium, Portugal and Thailand, respectively. However, considering grade, Belgium holds the first rank for 10th and 11th grade. Thailand has the lowest mean for all grades.

Focusing on science attitudes, Thailand shows the highest mean total and Portugal is second. Belgium is the third and Korean have the lowest mean in almost all grades.

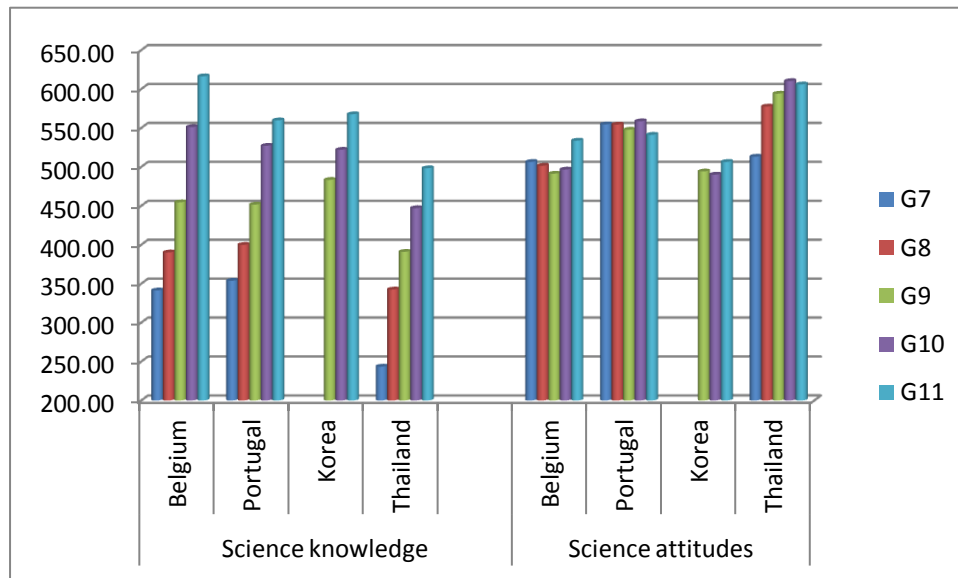


Figure 10. Science knowledge and attitudes by grade in each country

Table 18. Mean and Standard deviation of science knowledge and attitudes by books at home for each country

	Belgium (<i>N</i> = 8,857)		Portugal (<i>N</i> = 5,109)		Korea (<i>N</i> = 5,176)		Thailand (<i>N</i> = 6,192)	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Science Knowledge								
0-10 books	449.05	(91.55)	428.90	(76.53)	433.14	(80.19)	401.25	(66.23)
11-25 books	480.30	(88.64)	451.50	(77.90)	481.65	(83.53)	415.58	(68.71)
26-100 books	516.98	(86.78)	486.55	(75.89)	507.59	(80.42)	445.01	(77.54)
101-200 books	542.23	(84.90)	507.63	(77.83)	530.97	(79.83)	466.59	(87.09)
201-500 books	564.82	(77.53)	525.36	(77.42)	557.23	(79.29)	501.24	(84.94)
More than 500 books	561.52	(89.53)	534.39	(81.46)	517.64	(81.86)	510.69	(86.76)
Total	517.04	(94.24)	479.24	(84.03)	522.10	(86.89)	430.63	(78.79)
Science Attitudes								
0-10 books	478.39	(78.45)	547.98	(68.21)	463.90	(89.08)	593.45	(80.07)
11-25 books	487.41	(74.33)	553.29	(69.99)	474.86	(85.39)	602.01	(78.97)
26-100 books	492.79	(71.73)	555.96	(71.75)	480.22	(81.38)	610.07	(79.65)
101-200 books	503.03	(72.59)	554.98	(68.19)	493.03	(75.48)	620.44	(84.72)
201-500 books	509.33	(73.99)	556.13	(74.68)	503.41	(78.94)	623.17	(85.29)
More than 500 books	513.60	(84.88)	567.40	(77.16)	525.21	(90.64)	617.14	(84.36)
Total	495.88	(75.43)	554.65	(71.03)	490.23	(82.40)	605.13	(80.80)

Table 18 presents the mean and standard deviation of science knowledge and attitudes by books at home for the various countries. The highest total of science knowledge is in Korea, followed by Belgium and Portugal; Thailand has the lowest score. When looking at groups with different number of books at home,

Belgium generally comes first followed by Korea, or sometimes Portugal, and Thailand being the last.

In regard to science attitudes, Thailand has always the highest mean for the various groups of number of books at home. Portugal comes second and Belgium is the third, and Korea has the lowest score for this category.

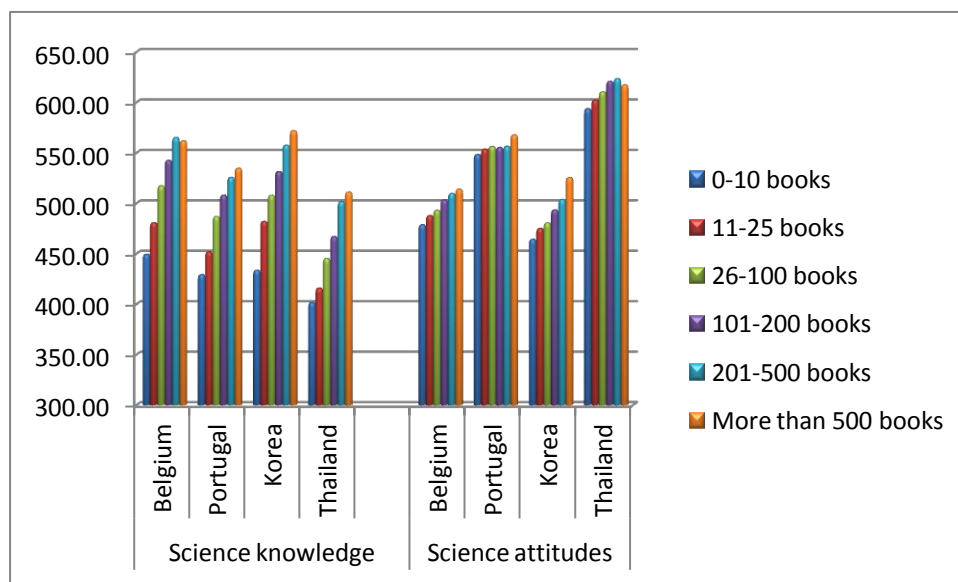


Figure 11. Science knowledge and attitudes by books at home in each country

2. Multivariate analysis of variance (MANOVA)

We explored group differences based on three relevant variables: gender (female and male), grade (7, 8, 9, 10 and 11) and books at home (0-10 books, 11-25 books, 26-100 books, 101-200 books, 201-500 books and More than 500 books) – using multivariate analysis of variance (MANOVA) (see table and figure below).

Table 19. Multivariate tests of gender, grade and books at home for each countries

Countries	Variables	Pillai's Trace	F	p
Belgium	Gender	.002	(2,8691) = 10.146	.000
	Grade	.224	(8,17384) = 274.414	.000
	Books at home	.006	(10,17384) = 5.655	.000
	Gender* Grade	.002	(8,17384) = 2.372	.015
	Gender* book at home	.003	(10,17384) = 2.651	.003
	Grade* book at home	.008	(38,17384) = 1.745	.003
	Gender*Grade* book at home	.006	(32,17384) = 1.587	.019
Portugal	Gender	.003	(2,4913) = 7.763	.000
	Grade	.304	(8,9828) = 220.006	.000
	Books at home	.011	(10,9828) = 5.406	.000
	Gender* Grade	.002	(8,9828) = 1.152	.325
	Gender* book at home	.003	(10,9828) = 1.717	.071
	Grade* book at home	.012	(36,9828) = 1.646	.009
	Gender*Grade* book at home	.006	(36,9828) = 0.830	.753

**p < .05*

Table 19. (Cont.)

Countries	Variables	Pillai's Trace	F	p
Korea	Gender	.001	(2,5131) = 2.230	.108
	Grade	.006	(4,10264) = 7.168	.000
	Books at home	.005	(10,10264) = 2.678	.003
	Gender* Grade	.001	(4,10264) = 0.734	.569
	Gender* book at home	.002	(10,10264) = 0.857	.573
	Grade* book at home	.003	(20,10264) = 0.688	.842
	Gender*Grade* book at home	.005	(18,10264) = 1.288	.184
Thailand	Gender	.000	(2,6068) = 0.526	.591
	Grade	.068	(8,12138) = 53.692	.000
	Books at home	.024	(10,12138) = 14.708	.000
	Gender* Grade	.002	(6,12138) = 2.473	.022
	Gender* book at home	.001	(10,12138) = 0.485	.901
	Grade* book at home	.020	(26,12138) = 4.702	.000
	Gender*Grade* book at home	.004	(26,12138) = 0.953	.531

**p < .05*

Regarding science knowledge and attitudes, multivariate tests show more significant effect in Belgium than in the other countries; in Korea, only grade and books and home generate significant group differences. More specifically:

- a) in Belgium, there a significant effect of gender, grade, books at home, gender*grade, gender* books at home, grade* books at home, and gender*grade* books at home;
- b) in Portugal, there is also a significant effect of gender, grade, books at home and grade* books at home;
- c) in Korea, results show a significant effect of grade, and books at home;
- d) in Thailand, there is also a significant effect of grade, books at home, gender* grade and grade* books at home.

Test of between-subject effects for each countries are presented in Tables 20, 21,22 and 23.

Table 20. Science knowledge and attitudes: *tests of between – subjects effects for Belgium*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	Science knowledge	72794.873	1	72794.873	13.502	.000
	Science attitudes	61626.422	1	61626.422	11.145	.001
Grade	Science knowledge	12889452.355	4	3222363.089	597.703	.000
	Science attitudes	55076.148	4	13769.037	2.490	.041
Books at home	Science knowledge	213842.935	5	42768.587	7.933	.000
	Science attitudes	120653.797	5	24130.759	4.364	.001
Gender*Grade	Science knowledge	41176.421	4	10294.105	1.909	.106
	Science attitudes	72835.402	4	18208.850	3.293	.011
Gender*Books at home	Science knowledge	60564.977	5	12112.995	2.247	.047
	Science attitudes	72516.723	5	14503.345	2.623	.022
Grade*Books at home	Science knowledge	85784.294	19	4514.963	.837	.663
	Science attitudes	292316.136	19	15385.060	2.782	.000
Gender*Grade*Books at home	Science knowledge	108639.297	16	6789.956	1.259	.214
	Science attitudes	149781.948	16	9361.372	1.693	.041

* $p < .05$

Table 20 shows the result of data analysis on variable effect of gender, grade and books at home as well as interaction of variables effect of gender*grade, gender*books at home, grade* books at home, and gender*grade*books at home on science knowledge and attitudes.

In Belgium, the results show that all variables have a significant effect on science knowledge. However, the interaction of variables is not significant for gender*grade (sig. = .106), gender*books at home (sig. = .047), grade* books at home (sig. = .663), and gender*grade*books at home (sig. = .214); only gender*books at home shows significant effects science knowledge. Regarding scientific attitudes all variables show significant main and interaction effects. The significant differences will be illustrated in the form of line graphs below.

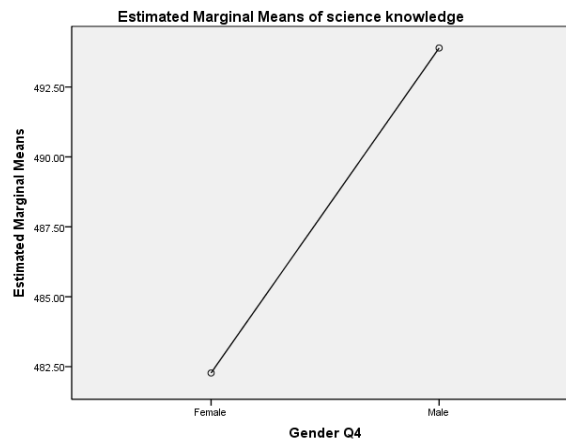


Figure 12. Science knowledge between female and male in Belgium

This graph shows that males have higher levels of science knowledge than females.

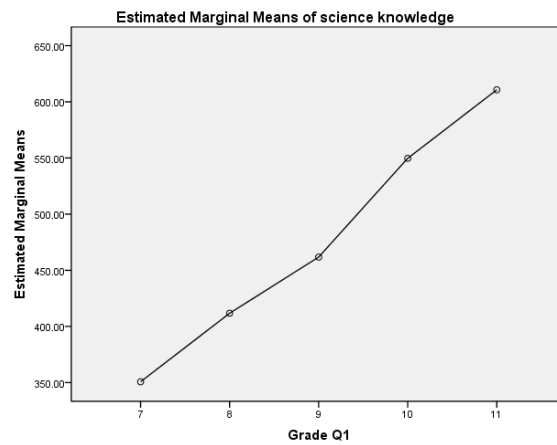


Figure 13. Science knowledge between each grade in Belgium

According to this graph, Grade 11 has the highest score of Science knowledge across all grades.

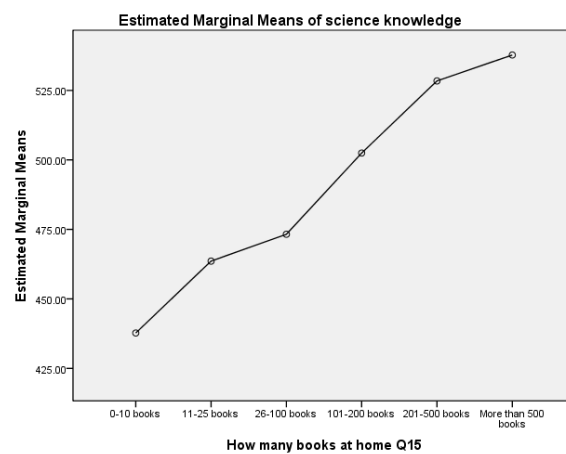


Figure 14. Science knowledge and number of books at home in Belgium

This graph shows a directly proportional relationship between dependent and independent variable: the more the number of books at home the more the science knowledge.

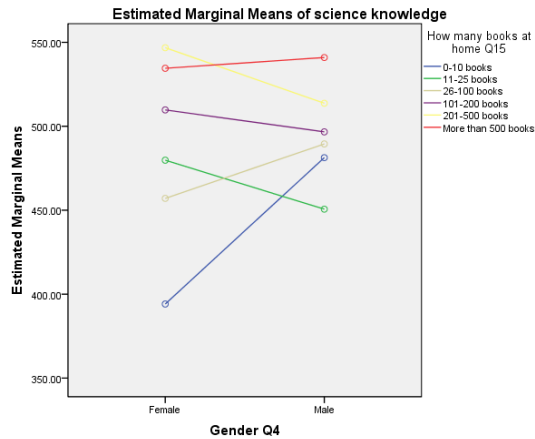


Figure 15. Relationship of gender, number of books at home and science knowledge in Belgium

According to the graph, female students that are in range of 11-25 books, 101-200 books and 201-500 books have higher levels of science knowledge than male students. On the other hand, male students in range of 0-10 books, 26-100 books and more than 500 books have higher levels of knowledge in science than female students.

The following graphs illustrate significant differences in what concerns science attitudes in Belgium.

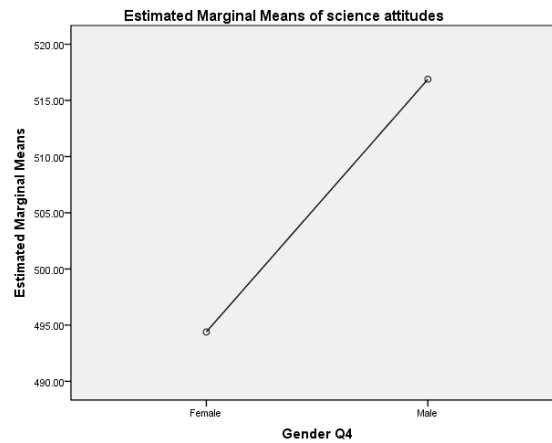


Figure 16. Science attitudes of female and male in Belgium

Male students have higher more positive attitudes towards science more than female.

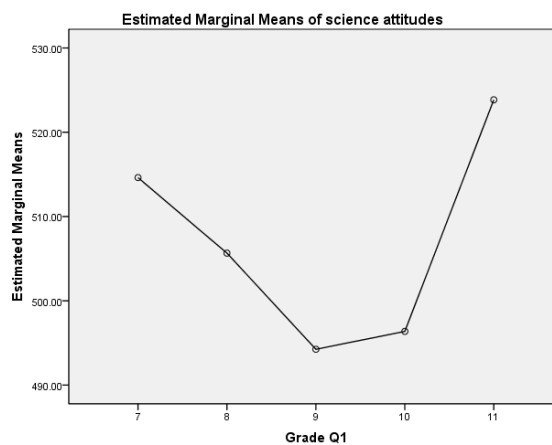


Figure 17. Relationship between grade and science attitudes in Belgium

According to this graph, from grade 7 to grade 9 there is a decreasing trend in science attitudes, that is clearly inverted from grade 10 to grade 11. Therefore, grade 11 has the more positive attitude towards science and grade 9 students the more negative.

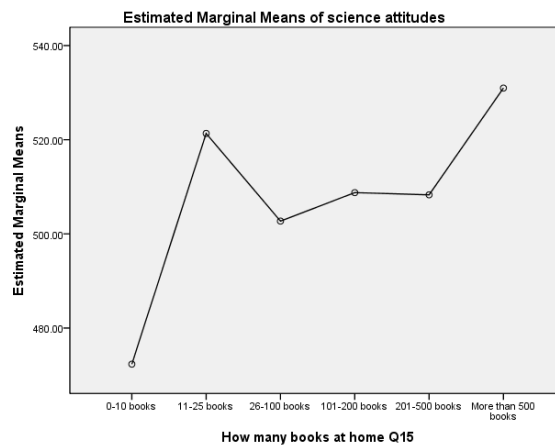


Figure 18. Relationship of number of books at home and science attitudes in Belgium

This graph displays that students with more than 500 books have the more positive science attitudes of, follow by students with 11-25 books; students with 0-10 books have the more negative science attitudes.

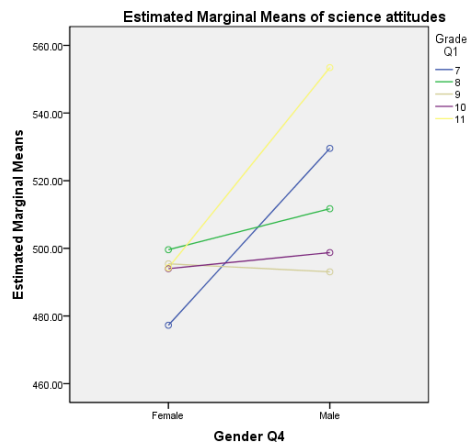


Figure 19. Relationship of gender, grade and science attitudes in Belgium

Male students in all grades except grade 9 have more positive science attitudes than female students.

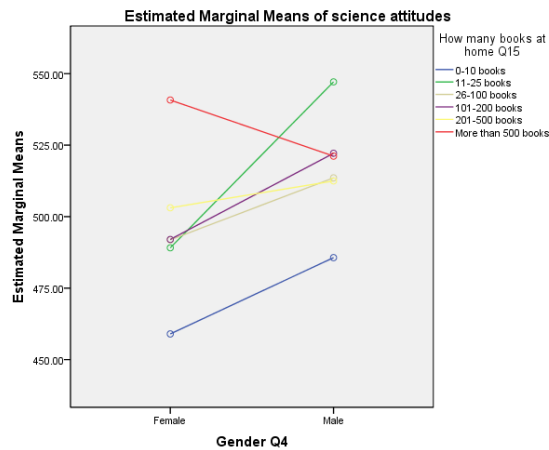


Figure 20. Relationship of gender, number of books at home and science attitudes in Belgium

Male students tend to have more positive attitudes towards science than female students; nonetheless, this profile is inverted for the students with more than 500 books, where female students are in advantage.

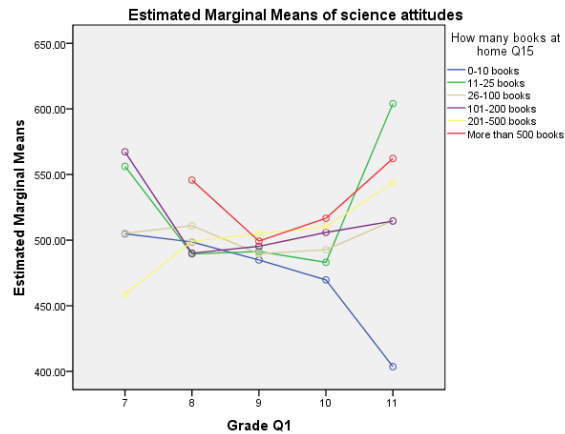


Figure 21. Relationship of grade, books at home and science attitudes in Belgium

There seems to be a complex interaction pattern between grade and books at home regarding attitudes towards science. In most groups, grade 11 students have more positive attitudes, with the exception of the group with fewer books that shows clearly more negative attitudes. The groups with more positive and negative attitudes are from grade 11 with 11-25 books and 0-10 books at home, respectively. In Grade 9, all students are similar attitudes independently of number of books at home.

Table 21. Science knowledge and attitudes: *tests of between – subjects effects for Portugal*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	Science knowledge	49968.363	1	49968.363	14.557	.000
	Science attitudes	544.856	1	544.856	.109	.741
Grade	Science knowledge	7243841.714	4	1810960.428	527.572	.000
	Science attitudes	79506.704	4	19876.676	3.989	.003
Books at home	Science knowledge	164603.294	5	32920.659	9.591	.000
	Science attitudes	26811.786	5	5362.357	1.076	.371
Gender*Grade	Science knowledge	16349.044	4	4087.261	1.191	.313
	Science attitudes	20883.372	4	5220.843	1.048	.381
Gender*Books at home	Science knowledge	31605.865	5	6321.173	1.841	.101
	Science attitudes	40844.006	5	8168.801	1.639	.146
Grade*Books at home	Science knowledge	117066.646	18	6503.703	1.895	.012
	Science attitudes	131299.476	18	7294.415	1.464	.093
Gender*Grade*Books at home	Science knowledge	44641.014	18	2480.056	.722	.791
	Science attitudes	81216.135	18	4512.008	.906	.572

* $p < .05$

In Portugal, the main variables have a significant effect on science knowledge, but only the interaction between grade*books at home is significant. Curiously, in Portugal only grade has a significant effect on science attitudes, and there is no significant interaction effect. The following graphs illustrate the significant differences between groups.

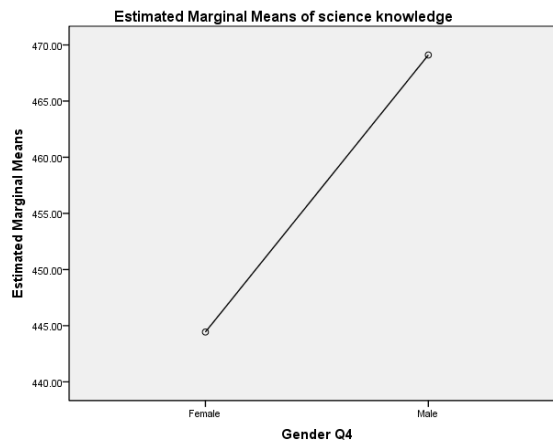


Figure 22. Science knowledge between female and male in Portugal

As shown in the graph, male students have higher levels of science knowledge than female.

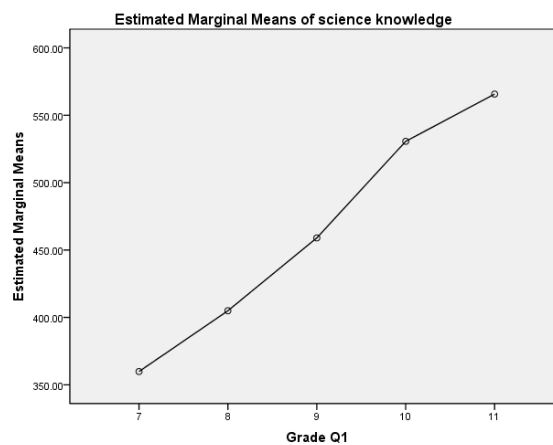


Figure 23. Science knowledge between each grade in Portugal

This graph shows a directly proportional relationship between both variables: the higher the grade the better the science knowledge.

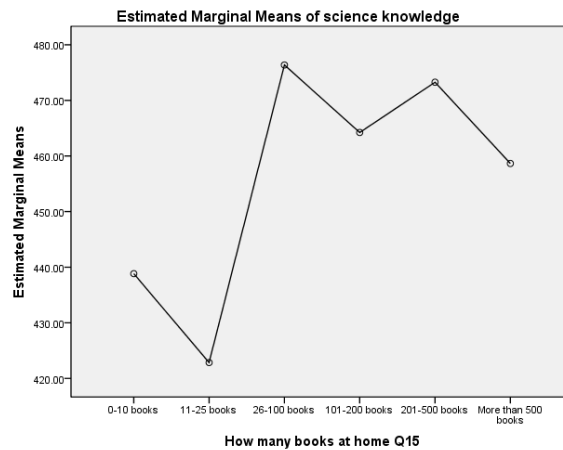


Figure 24. Science knowledge and number of books at home in Portugal

Students with books between 11-25 books have the lowest level of knowledge in science; on the whole, students with fewer books have lower levels of knowledge; students with books between 26-100 books have the highest level of science knowledge.

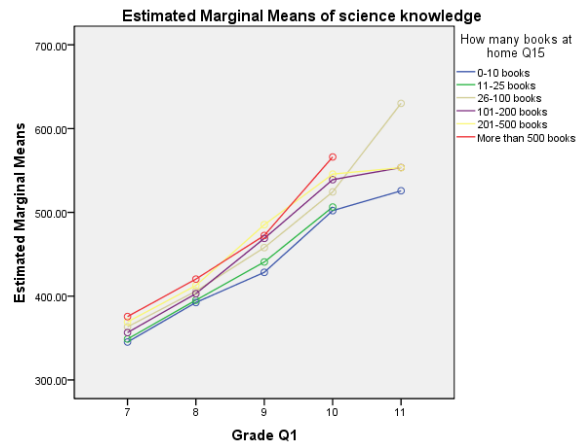


Figure 25. Relationship between grade, number of books at home and science knowledge in Portugal

Grade 7 students with all range of number of books at home have the lowest levels of science knowledge; across grades there is always a tendency for an increase in knowledge with more books at home, particularly expressive with the group with 26-100 books at home, that has the highest level science knowledge. However grade 11 does not have a range of more than 500 books shown in graph.

The following graph considers the significant differences of grade in science attitudes in Portugal.

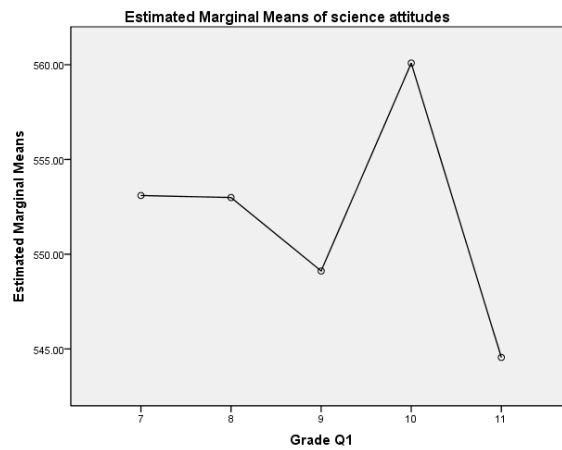


Figure 26. Relationship between grade and science attitudes in Portugal

Grade 10 students have the more positive science attitudes and grade 11 students have the less positive science attitudes.

Table 22. Science knowledge and attitudes: *tests of between – subjects effects for Korea*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	Science knowledge	12440.424	1	12440.424	1.937	.164
	Science attitudes	6746.800	1	6746.800	1.031	.310
Grade	Science knowledge	172819.484	2	86409.742	13.452	.000
	Science attitudes	32220.956	2	16110.478	2.462	.085
Books at home	Science knowledge	149840.329	5	29968.066	4.665	.000
	Science attitudes	47596.595	5	9519.319	1.455	.201
Gender*Grade	Science knowledge	9677.903	2	4838.951	.753	.471
	Science attitudes	4488.274	2	2244.137	.343	.710
Gender*Books at home	Science knowledge	18809.255	5	3761.851	.586	.711
	Science attitudes	25412.295	5	5082.459	.777	.566
Grade*Books at home	Science knowledge	65169.380	10	6516.938	1.015	.428
	Science attitudes	39073.161	10	3907.316	.597	.818
Gender*Grade*Books at home	Science knowledge	64894.134	9	7210.459	1.123	.342
	Science attitudes	78862.343	9	8762.483	1.339	.211

* $p < .05$

In Korea, only grade and books at home have a significant effect on science knowledge. There are no interaction effects, and there are no significant differences on science attitudes. The graphs below illustrate the significant differences.

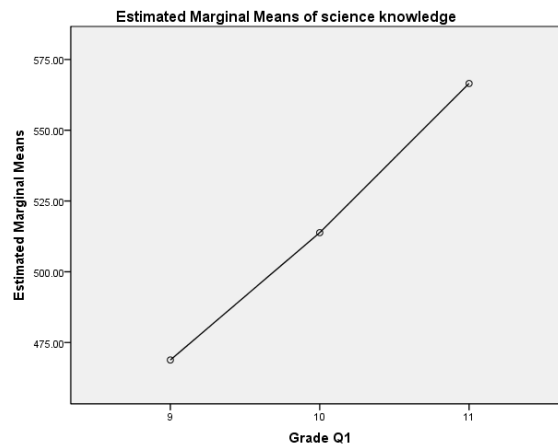


Figure 27. Science knowledge between each grade in Korea

From grade 9 to grade 11 graph there is an increasing trend which means that the higher the grade the higher the science knowledge.

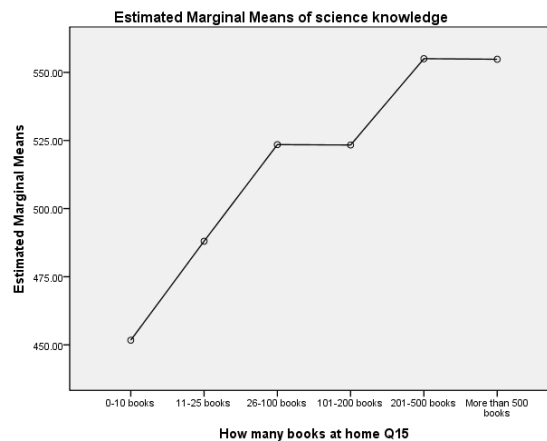


Figure 28. Science knowledge and number of books at home in Korea

Students with books at home between 0-10 books has the lowest science knowledge and students in both range of 201-500 books and more than 500 books have the highest science knowledge.

Table 23. Science knowledge and attitudes: *Tests of Between – Subjects Effects for Thailand*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	Science knowledge	340.466	1	340.466	.073	.788
	Science attitudes	5293.438	1	5293.438	.832	.362
Grade	Science knowledge	2061676.536	4	515419.134	109.874	.000
	Science attitudes	80356.112	4	20089.028	3.157	.013
Books at home	Science knowledge	674680.891	5	134936.178	28.765	.000
	Science attitudes	56812.971	5	11362.594	1.785	.112
Gender*Grade	Science knowledge	49820.392	3	16606.797	3.540	.014
	Science attitudes	26141.937	3	8713.979	1.369	.250
Gender*Books at home	Science knowledge	6466.103	5	1293.221	.276	.927
	Science attitudes	25061.774	5	5012.355	.788	.558
Grade*Books at home	Science knowledge	487056.711	13	37465.901	7.987	.000
	Science attitudes	86769.647	13	6674.588	1.049	.400
Gender*Grade*Books at home	Science knowledge	76769.361	13	5905.335	1.259	.230
	Science attitudes	37438.994	13	2879.923	.453	.950

* $p < .05$

In Thailand, the results are similar to Korea with significant effects of grade and books at home; there are also interaction effects on science knowledge for gender*grade (sig. = .014) and grade*books at home (sig. = .000). For science attitudes only grade generates significant differences. The graphs below illustrate these significant differences.

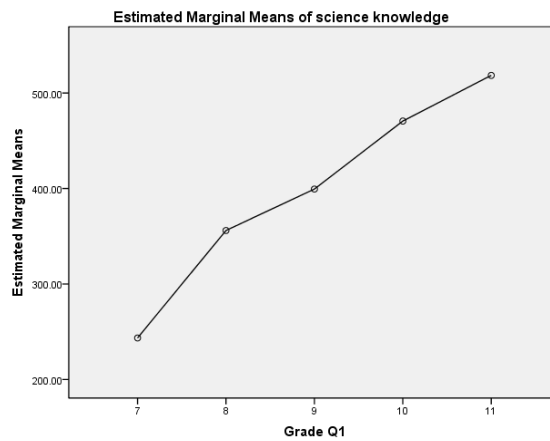


Figure 29. Science knowledge between each grade in Thailand

According to the graph, the higher the grade the higher the science knowledge.

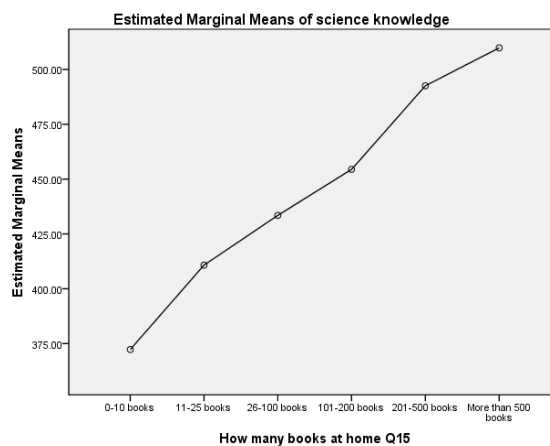


Figure 30. Science knowledge and number of books at home in Thailand

This graph shows that the higher the number of books at home the higher the science knowledge.

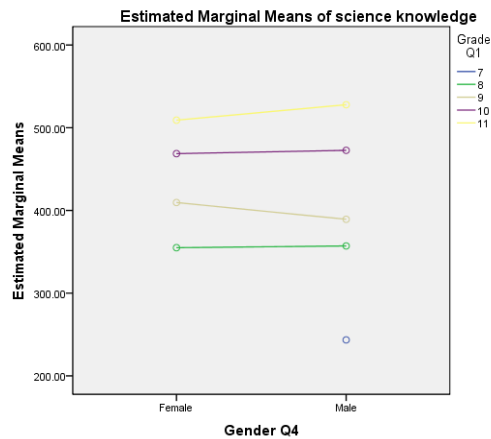


Figure 31. Relationship of gender, grade and science knowledge in Thailand

From this graph we can see that the pattern of male and female differences in science knowledge varies across grade.

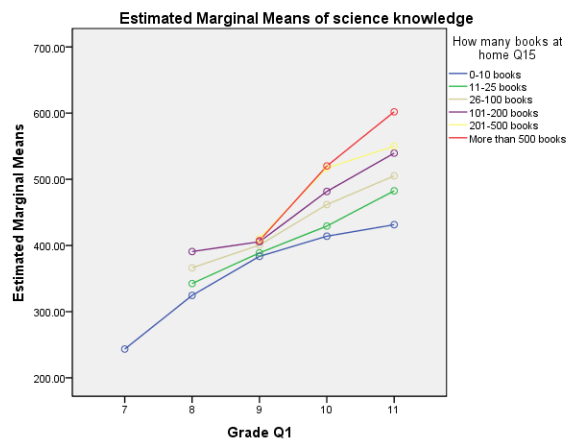


Figure 32. Relationship of grade, number of books at home and science knowledge in Thailand

The global tendency is for an increase in grade resulting in an increase in science knowledge across groups with different books at home, but this is more

expressive in some groups than others: for instance, in grade 9 differences between groups with variations in books at home are almost inexistant. Grade 7 has the lowest level of science knowledge for the group with the fewer number of books at home and grade 11 has the highest level of science knowledge for the group with the higher number of books at home.

The following graph considers vearions in science attitudes in Thailand.

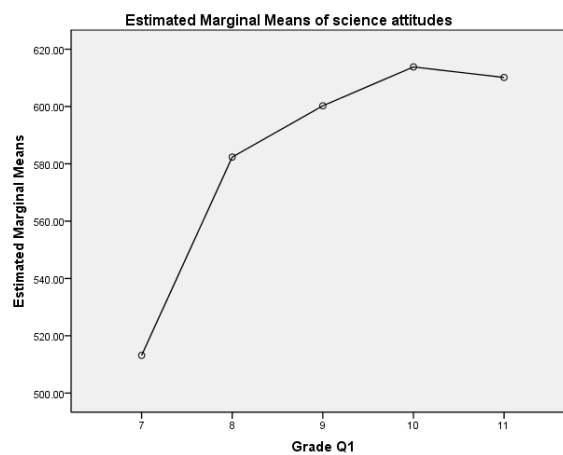


Figure 33. Relationship between grade and science attitudes in Thailand

The higher the grade the more positive the science attitude, except for grade 11 that has the second more positive attitudes.

As shown in Table 24, in Belgium and Portugal, male reveal significantly higher levels of both science knowledge and attitudes than female. In Thailand and Korea there are no significant gender difference.

3. Correlation between variables

The correlation analysis between variables was performed by computing Pearson's correlation coefficient; correlations between science knowledge and attitudes and other variables are presented in Table 24 and Table 25.

Table 24. Correlations between variables of science knowledge

Variables	Science knowledge	Science teaching	Science self-efficacy	Science attitudes
Science knowledge	1.00			
Science teaching	-.280**	1.00		
Science self-efficacy	.263**	.220**	1.00	
Science attitudes	-.044**	.446**	.395**	1.00

Note. *significant at .01; (*p < .01), *significant at .05; (*p < .05)

Considering the correlation coefficient between the 4 variables, science knowledge is mostly correlated with science self-efficacy (.263). It is interesting to note that the correlation with science teaching is negative.

Table 25. Correlations between variables of science attitudes

Variables	Science attitudes	Science teaching	Science self-efficacy
Science attitudes	1.00		
Science teaching	.446**	1.00	
Science self-efficacy	.395**	.220**	1.00

Note. *significant at .01; (* $p < .01$), *significant at .05; (* $p < .05$)

As see on table 25, the correlation coefficient between science attitudes is high with science teaching (.446) and science self-efficacy (.395).

4. Multiple Regression Analysis

The series of multiple regression analysis of predictors for scientific knowledge among European and Asian countries are presented in Table 26 for Adjusted R Square Multiple Regression and Table 27 for Standardized Regression Coefficients.

Table 26. Adjusted R Square Multiple Regression of predictors for knowledge among European and Asian countries

Models	Knowledge (Adjusted R Square)			
	Europe		Asia	
	Belgium (high)	Portugal (low)	Korea (high)	Thailand (low)
1. Student characteristics	.285	.483	.008	.148
2. Student characteristics and Family background	.373	.525	.178	.318
3. Student characteristics, Family background and Teaching of science	.478	.566	.266	.340
4. Student characteristics, Family background, Teaching of science and ICT	.479	.570	.274	.367
5. Student characteristics, Family background, Teaching of science, ICT and enjoyment/ Self-efficacy	.542	.630	.396	.403

Table 27. Standardized Regression Coefficients of knowledge among European and Asian countries

Variables	Knowledge							
	Europe				Asia			
	Belgium (high)		Portugal (low)		Korea (high)		Thailand (low)	
	Beta (β)	Sig.	Beta (β)	Sig.	Beta (β)	Sig.	Beta (β)	Sig.
- Gender	-.061	.000*	-.111	.000*	-.009	.437	.033	.002*
- Grade	.352	.000*	.537	.000*	.045	.000*	.241	.000*
- Age of student	-.018	.030*	-.046	.000*	.052	.000*	-.009	.424
- Educational level of mother	.058	.000*	.056	.000*	.013	.369	.086	.000*
- Educational level of father	.030	.002*	.005	.725	.062	.000*	.144	.000*
- Family wealth PISA 2006	.014	.123	.007	.541	-.015	.237	.150	.000*
- Cultural possessions at home	.048	.000*	.026	.038*	.097	.000*	.001	.906
- How many book at home	.135	.000*	.108	.000*	.176	.000*	.130	.000*
- Science Teaching-Focus on applications or models	.148	.000*	.092	.000*	.166	.000*	.104	.000*
- Science Teaching-Hands on activities	.106	.000*	.022	.091	.008	.586	.037	.016*
- Science Teaching-Interaction	-.084	.000*	-.060	.000*	-.138	.000*	-.081	.000*
- Science Teaching-Student investigations	-.295	.000*	-.196	.000*	-.206	.000*	-.108	.000*
- ICT Internet/entertainment use	.030	.003*	.015	.234	-.070	.000*	.094	.000*
- ICT Program/software use	-.073	.000*	-.096	.000*	-.006	.642	-.234	.000*
- Science self-efficacy	.198	.000*	.146	.000*	.181	.000*	.077	.000*
- Enjoyment of science	.126	.000*	.174	.000*	.270	.000*	.164	.000*

Note. The values represent standardized beta coefficients (β), *significant at .05; (* $p < .05$)

On the whole, results show that the predictors explains a high degree of variance of students' science knowledge, but the percentage of variance explained is higher in European countries (Belgium = 54.2%, Portugal = 63.0%) than in Asian countries (Korea = 39.6%, Thailand = 40.3%), independently of their status as "low-achievers" and "high-achievers". In European countries, student characteristics play a very important role in explaining differences of knowledge (Belgium = 28.5%, Portugal = 48.3%); in Asian countries, the percentage of

variance explained by these variables is less relevant (Korea = 0.8%, Thailand = 14.8%). However, in both regions, gender and grade are more significant in countries where the level of knowledge is lower. Family background is the strongest predicting variable in Asian countries; however, there were significant differences in the specific variables that account for the differences – suggesting that contextual variables are playing an important role in the development of scientific knowledge. In both regions, the teaching of science makes a relevant (but low) contribution for student's knowledge (with an increase in approximately 2-10% in explained variance across countries). The role of self-efficacy also seems to be quite important and stable across regions and countries (see Table 26).

The series of multiple regression analysis of predictors for scientific attitudes among European and Asian countries are presented in Table 28 for Adjusted R Square Multiple Regression and Table 29 for Standardized Regression Coefficients.

Table 28. Adjusted R Square Multiple Regression of predictors for attitudes among European and Asian countries

Models	Attitudes (Adjusted R Square)			
	Europe		Asia	
	Belgium (high)	Portugal (low)	Korea (high)	Thailand (low)
1. Student characteristics	.002	.004	.007	.014
2. Student characteristics and Family background	.042	.021	.074	.032
3. Student characteristics, Family background and Teaching of science	.093	.127	.130	.143
4. Student characteristics, Family background, Teaching of science and ICT	.103	.138	.142	.143
5. Student characteristics, Family background, Teaching of science, ICT and Science self-efficacy	.206	.229	.260	.225

Table 28 the results of predictors of students' attitudes explains a similar degree of variance for both European and Asian countries (Portugal = 22.9%, Belgium = 20.6%, Thailand = 22.5% and Korea = 26.0%). Individual level variables (science self-efficacy) are the most influential in scientific attitudes.

Table 29. Standardized Regression Coefficients of attitudes among European and Asian countries

Variables	Attitudes							
	Europe				Asia			
	Belgium (high)		Portugal (low)		Korea (high)		Thailand (low)	
	Beta (β)	Sig.	Beta (β)	Sig.	Beta (β)	Sig.	Beta (β)	Sig.
- Gender	.021	.077	.045	.003*	.076	.000*	-.038	.002*
- Grade	-.032	.009*	.014	.411	-.009	.474	.068	.000*
- Age of student	.036	.001*	.017	.258	.044	.000*	-.015	.233
- Educational level of mother	-.031	.016*	-.009	.663	.009	.572	.020	.260
- Educational level of father	.019	.131	-.039	.054	.024	.140	.019	.281
- Family wealth PISA 2006	-.061	.000*	-.058	.001*	.038	.005*	-.053	.001*
- Cultural possessions at home	.075	.000*	.052	.004*	.067	.000*	.014	.266
- How many book at home	.034	.007*	-.028	.142	.015	.305	.038	.005*
- Science Teaching-Focus on applications or models	.128	.000*	.240	.000*	.182	.000*	.240	.000*
- Science Teaching-Hands on activities	-.016	.255	.022	.240	.037	.017*	.033	.062
- Science Teaching-Interaction	.060	.000*	.026	.180	.013	.448	.016	.367
- Science Teaching-Student investigations	.014	.313	-.037	.061	-.053	.003*	-.019	.264
- ICT Internet/entertainment use	-.075	.000*	-.067	.000*	-.024	.103	-.014	.390
- ICT Program/software use	.079	.000*	.116	.000*	.057	.000*	.004	.819
- Science self-efficacy	.348	.000*	.326	.000*	.373	.000*	.307	.000*

Note. The values represent standardized beta coefficients (β), *significant at .05; (* $p < .05$)

5. Multiple Group Analysis

The invariance of the measurement model and of the structural model for science knowledge and science attitudes predictors in PISA 2006 in four countries (e.g. Belgium, Portugal, Korea, and Thailand) was analyzed with software AMOS (v.19, SPSS Inc, Chicago, IL.). First the model was adjusted for the four groups by removing the items that did not contributed for the quality of the model. Secondly, the invariance of the model was evaluated in the four groups by comparison of the unconstricted model (with free factorial weights and variances/ covariances of the factors) with a constrained model where the factorial weights and the factorial variance/ covariance of the four groups are fixed. The statistical significance of the difference of the four models was performed with the Chi-square test.

Figures 34, 35, 36 and 37 illustrate the estimates of the factorial weights and of direct effects in the unconstrained causal model of science knowledge predictors of PISA 2006 in four groups (e.g. Belgium, Portugal, Korea, Thailand). The adjustment indexes of the unconstrained causal model are: CFI = .912, RMSEA= .043 [C.I. 90% for RMSEA = .042, .044]. The constricted model (with fixed factorial weights and factorial variance/ covariance of the four groups) presents an adjustment that is significantly worse than the unconstrained model with free parameters. ($\chi^2_{df}(148) = 5980.865, p = .000$).

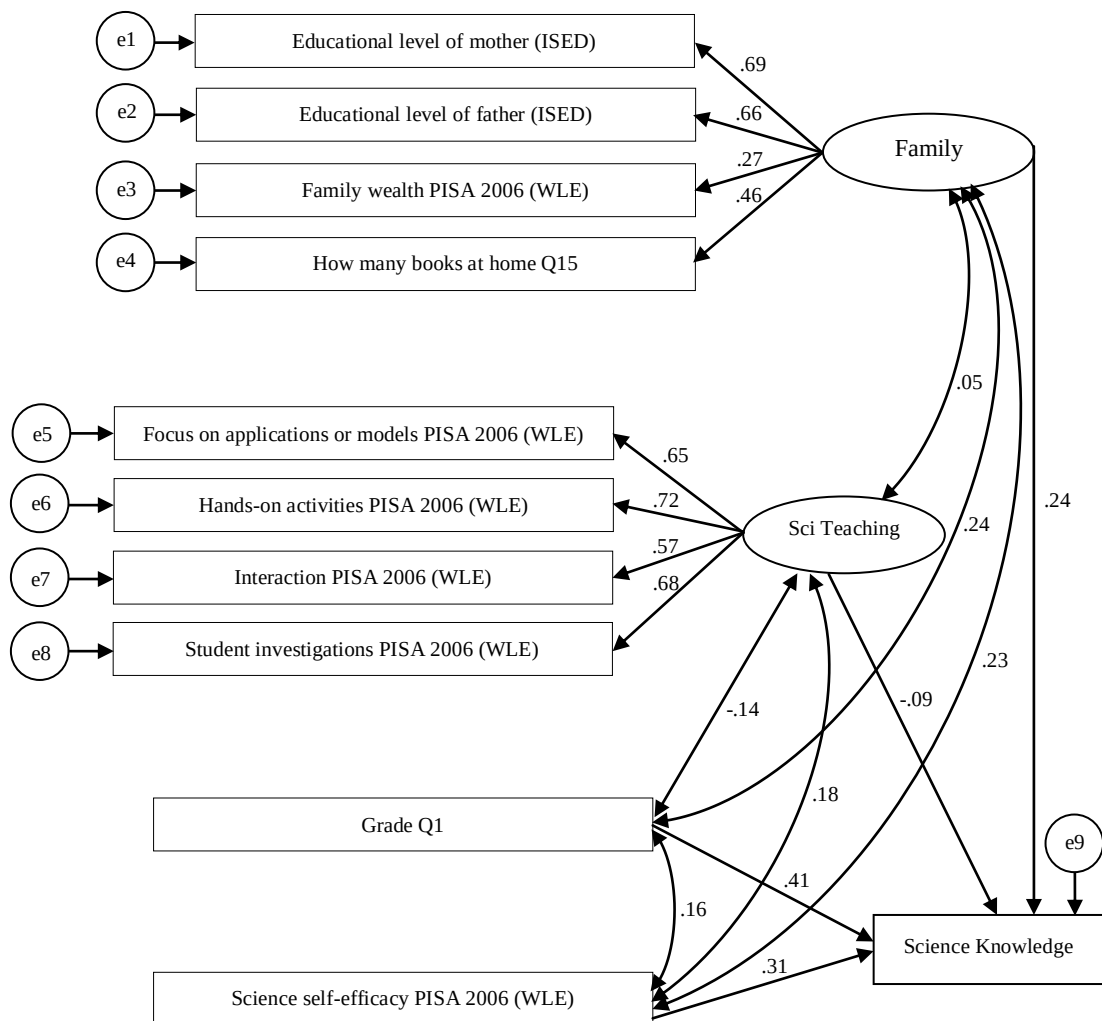


Figure 34. Model for the predictors of science knowledge for Belgium

In Belgium, grade (0.41) is the best predictors of student's science knowledge, the second is science self-efficacy (0.31), the third is family background (0.24) and the worst is science teaching variable (-0.09).

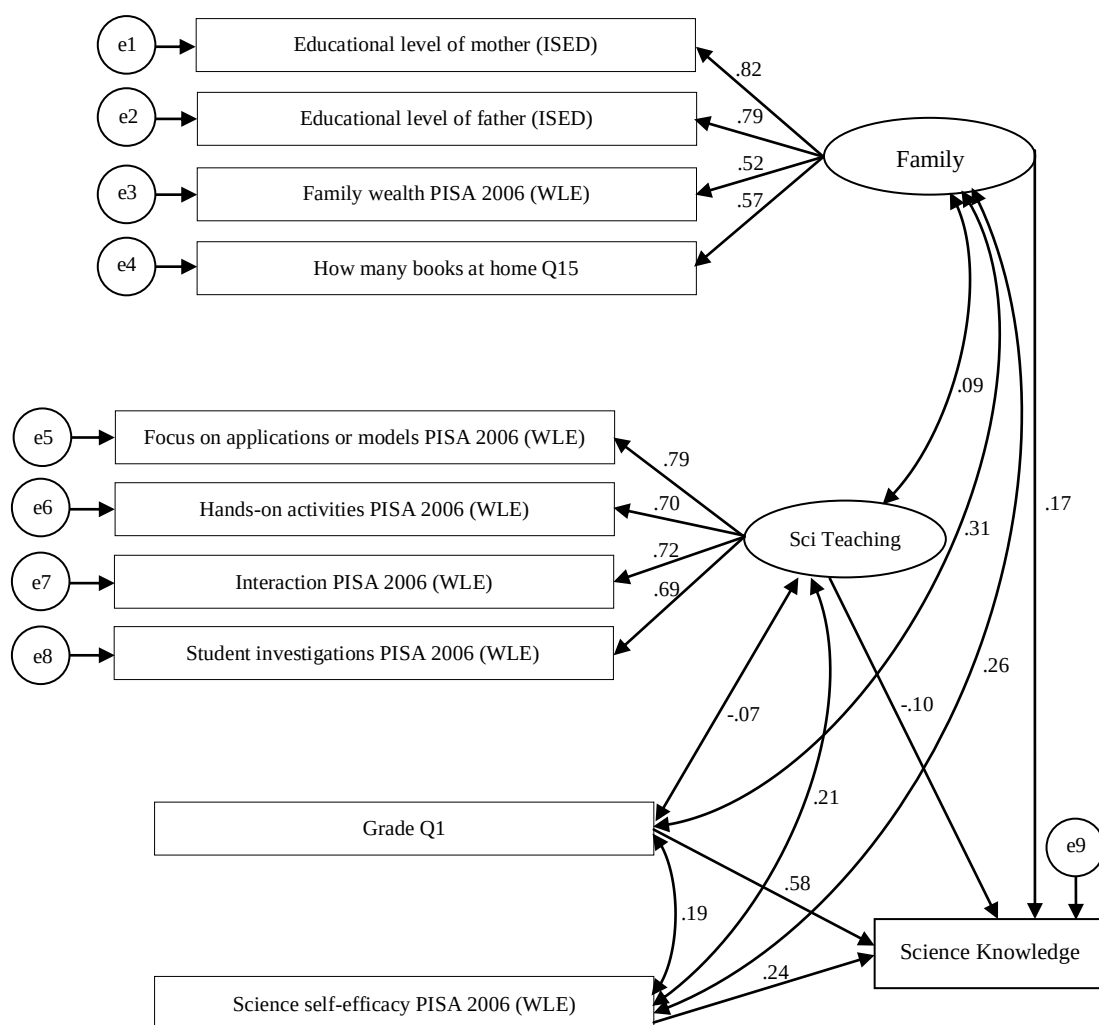


Figure 35. Model for the predictors of science knowledge for Portugal

In Portugal, grade (0.58) is the best predictor of student's science knowledge, the second is science self-efficacy (0.24), the third is family background (0.17) and the worst is science teaching (-0.10). Therefore, the profile for Portugal and Belgium is very similar.

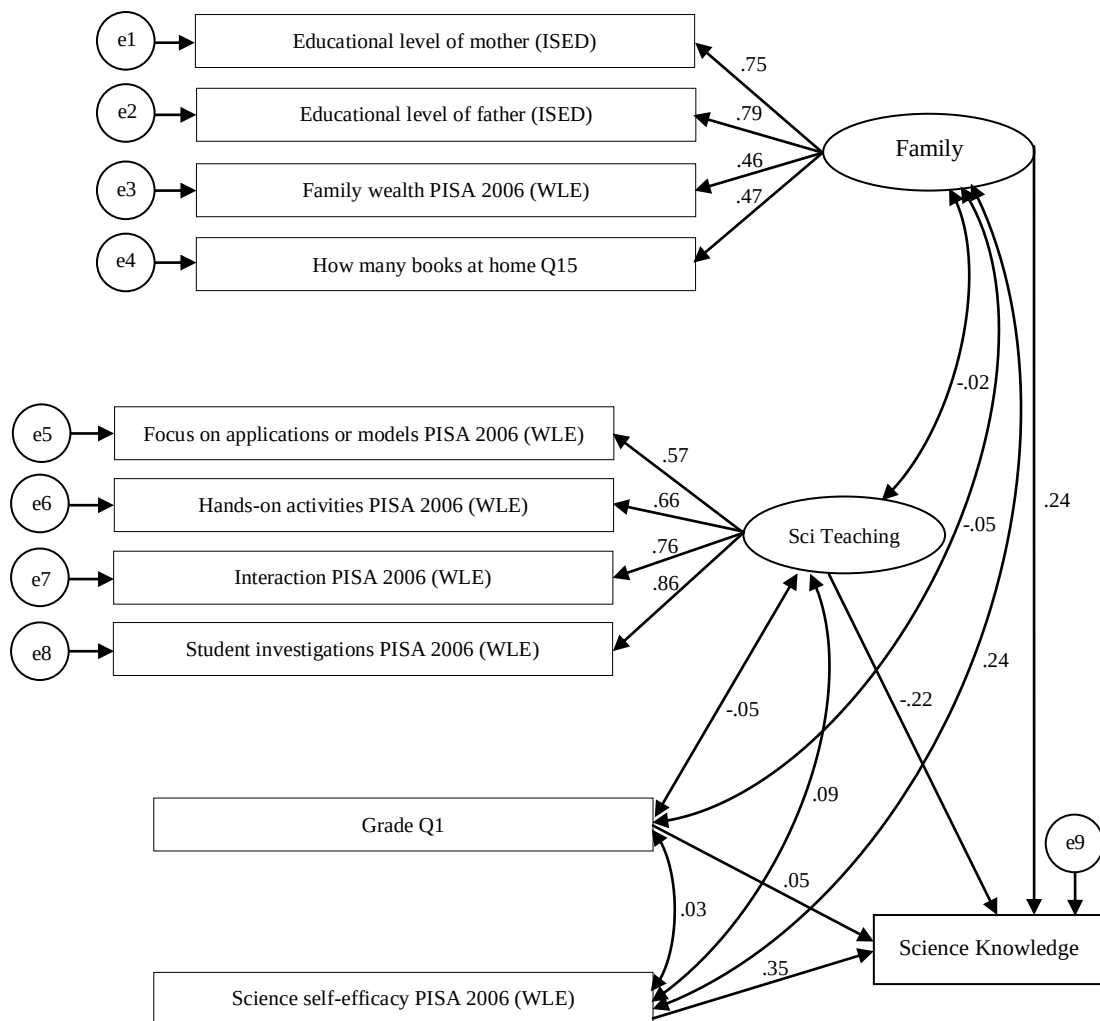


Figure 36. Model for the predictors of science knowledge for Korea

In Korea, science self-efficacy(0.35) is the best predictor of student's science knowledge, the second is family background (0.24), the third is grade (0.05) and the worst is science teaching (-0.22).

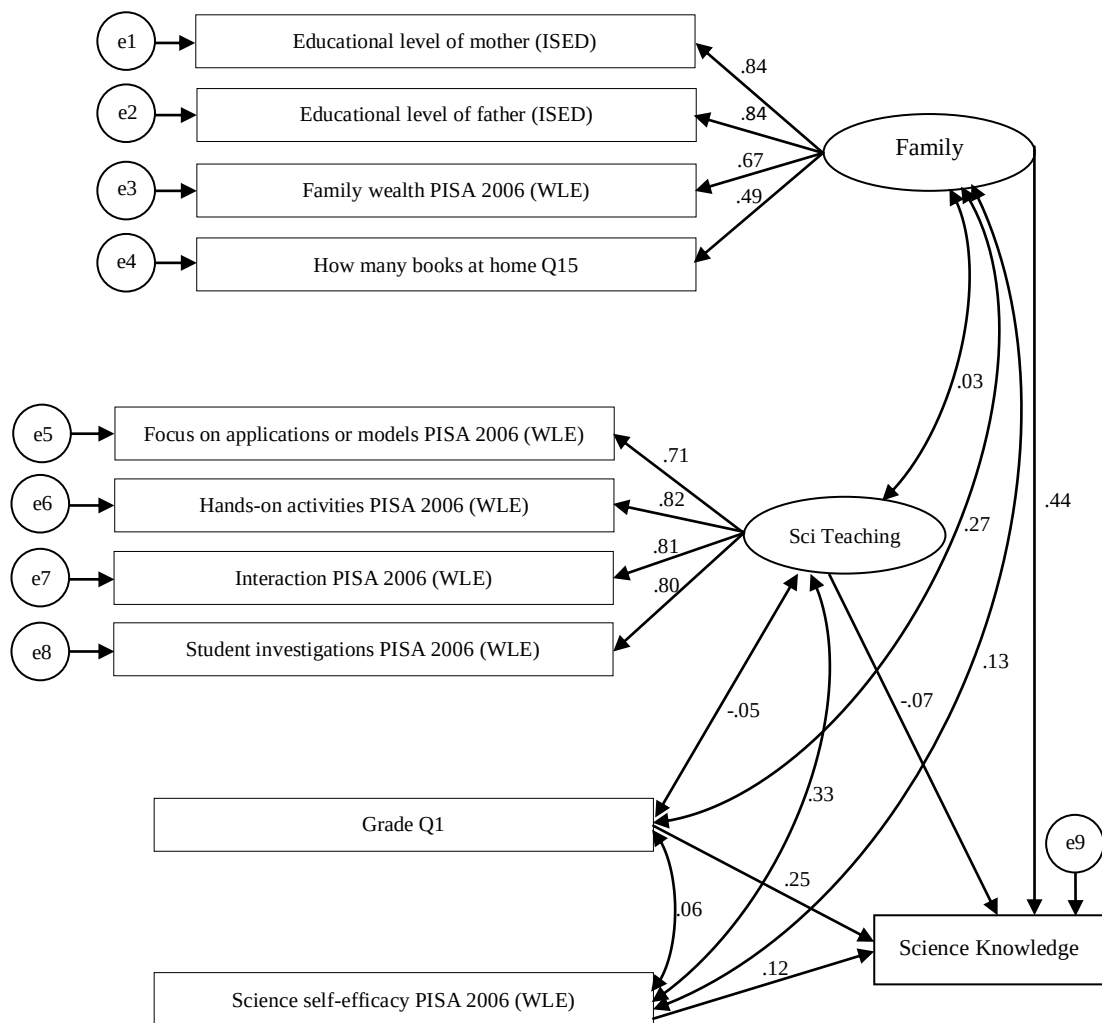


Figure 37. Model for the predictors of science knowledge for Thailand

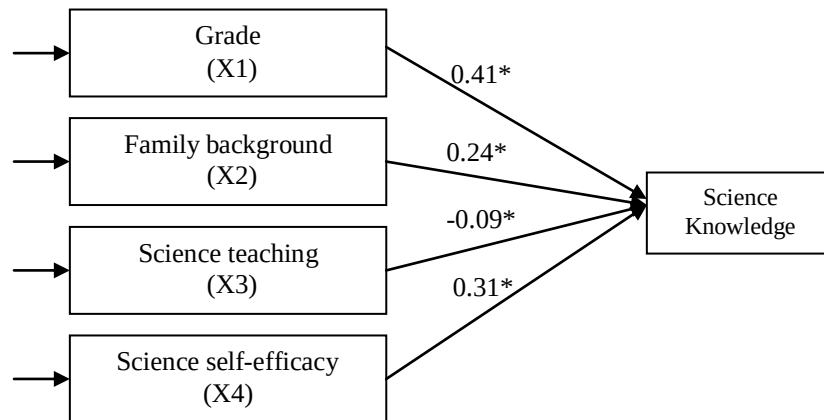
In Thailand, family background (0.44) is the best predictor of student's science knowledge, the second is grade (0.25), the third is science self-efficacy variable (0.12) and the worst is science teaching (-0.07).

Table 30. Results of Multiple Group Analysis of science knowledge for four countries

Variables	β_{Belgium}	β_{Portugal}	β_{Korea}	β_{Thailand}
Grade Q1	0.41	0.58	0.05	0.25
Family background	0.24	0.17	0.24	0.44
Science Teaching	-0.09	-0.10	-0.22	-0.07
Science self-efficacy	0.31	0.24	0.35	0.12
CFI = 0.912, RMSEA= 0.043 [C.I. 90% for RMSEA = .042, .044]				
Chi-square = 5980.865, df = 148, p-value = 0.000				

From Table 30 the results of Multiple Group Regression Analysis of student's science knowledge by Multiple Regression Method show that the 4 variables which lead into equation by order are grade, family background, science teaching and science self-efficacy.

The result of analysis found that the model has Chi-square = 5980.865 (p=.000), df = 148, CMIN/DF = 40.411, CFI = .912 and RMSEA = .043.

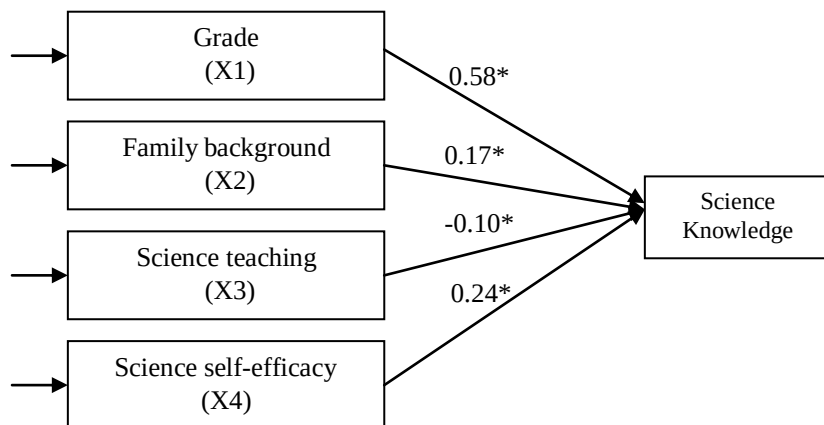


* $p < .05$

Figure 38. Multiple regression model for the predictors of science knowledge for Belgium

From the model figure 38 can make the Multiple Regression equation of standard scores to predict science knowledge for Belgium as follow:

$$Z_{Science\ Knowledge} = 0.41Z_{Grade} + 0.24Z_{Family} - 0.09Z_{Sci\ Teaching} + 0.31Z_{Science\ self-efficiency}$$

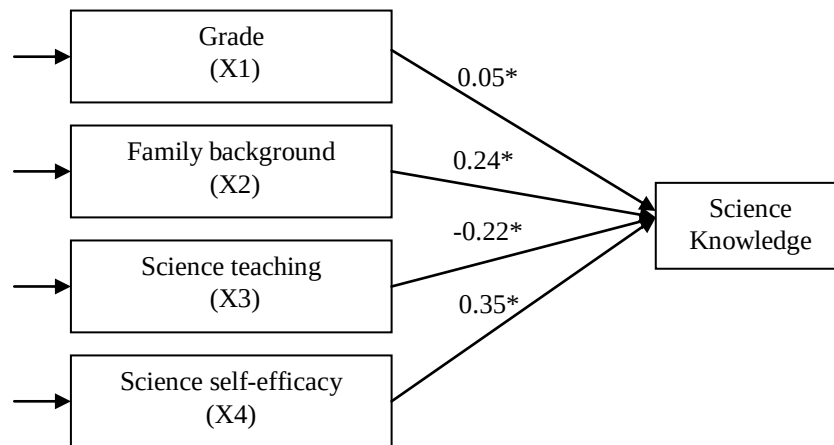


* $p < .05$

Figure 39. Multiple regression model for the predictors of science knowledge for Portugal

From the model figure 39 can make the Multiple Regression equation of standard scores to predict science knowledge for Portugal as follow:

$$Z_{Science\ Knowledge} = 0.58Z_{Grade} + 0.17Z_{Family} - 0.10Z_{Sci\ Teaching} + 0.24Z_{Science\ self-efficiency}$$

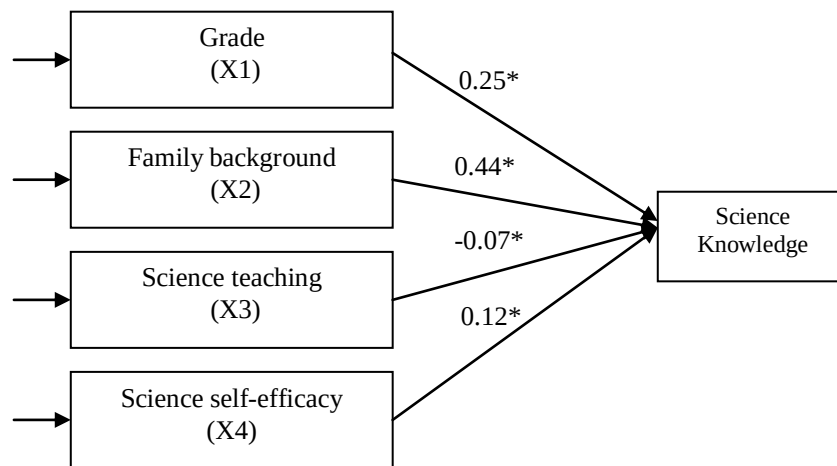


* $p < .05$

Figure 40. Multiple regression model for the predictors of science knowledge for Korea

From the model figure 40 can make the Multiple Regression equation of standard scores to predict science knowledge for Korea as follow:

$$Z_{Science\ Knowledge} = 0.05Z_{Grade} + 0.24Z_{Family} - 0.22Z_{Sci\ Teaching} + 0.35Z_{Science\ self-efficiency}$$



* $p < .05$

Figure 41. Multiple regression model for the predictors of science knowledge for Thailand

From the model figure 41 can make the Multiple Regression equation of standard scores to predict science knowledge for Thailand as follow:

$$Z_{Science\ Knowledge} = 0.25Z_{Grade} + 0.44Z_{Family} - 0.07Z_{Sci\ Teaching} + 0.12Z_{Science\ self\ -efficacy}$$

Figures 42, 43, 44 and 45 illustrate the estimates of the factorial weights and of direct effects in the unconstrained causal model of science attitudes predictors of PISA 2006 in four groups (e.g. Belgium, Portugal, Korea, Thailand). The adjustment indexes of the unconstrained causal model are: CFI = .949, RMSEA= .033 [C.I. 90% for RMSEA = .032, .034]. The constricted model (with fixed factorial weights and factorial variance/ covariance of the four groups)

presents an adjustment that is significantly worse than the unconstrained model with free parameters. ($\chi^2_{df}(124) = 3019,060, p = .000$).

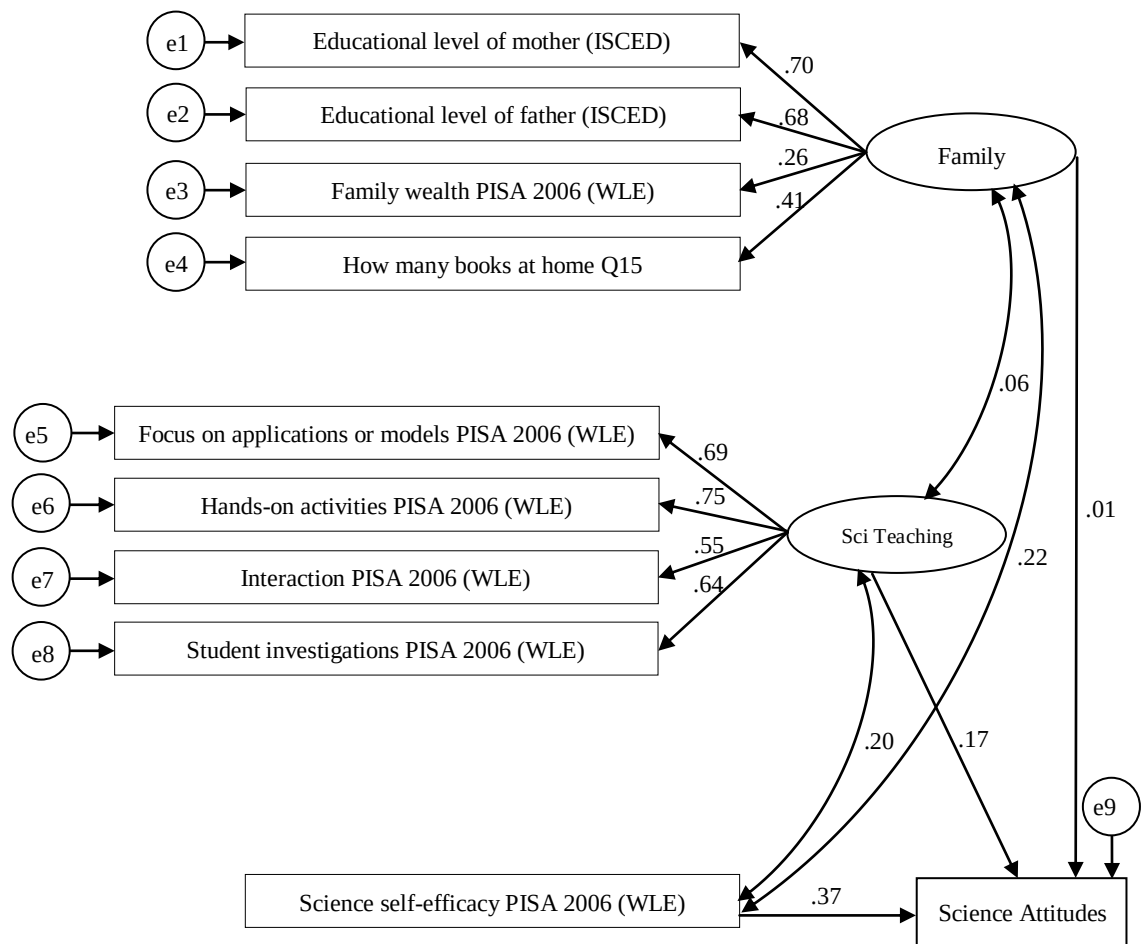


Figure 42. Model for the predictors of science attitudes for Belgium

In Belgium, science self-efficacy (0.37) is the best predictor of student's science attitudes, the second is science teaching (0.17), and the third is family background (0.01).

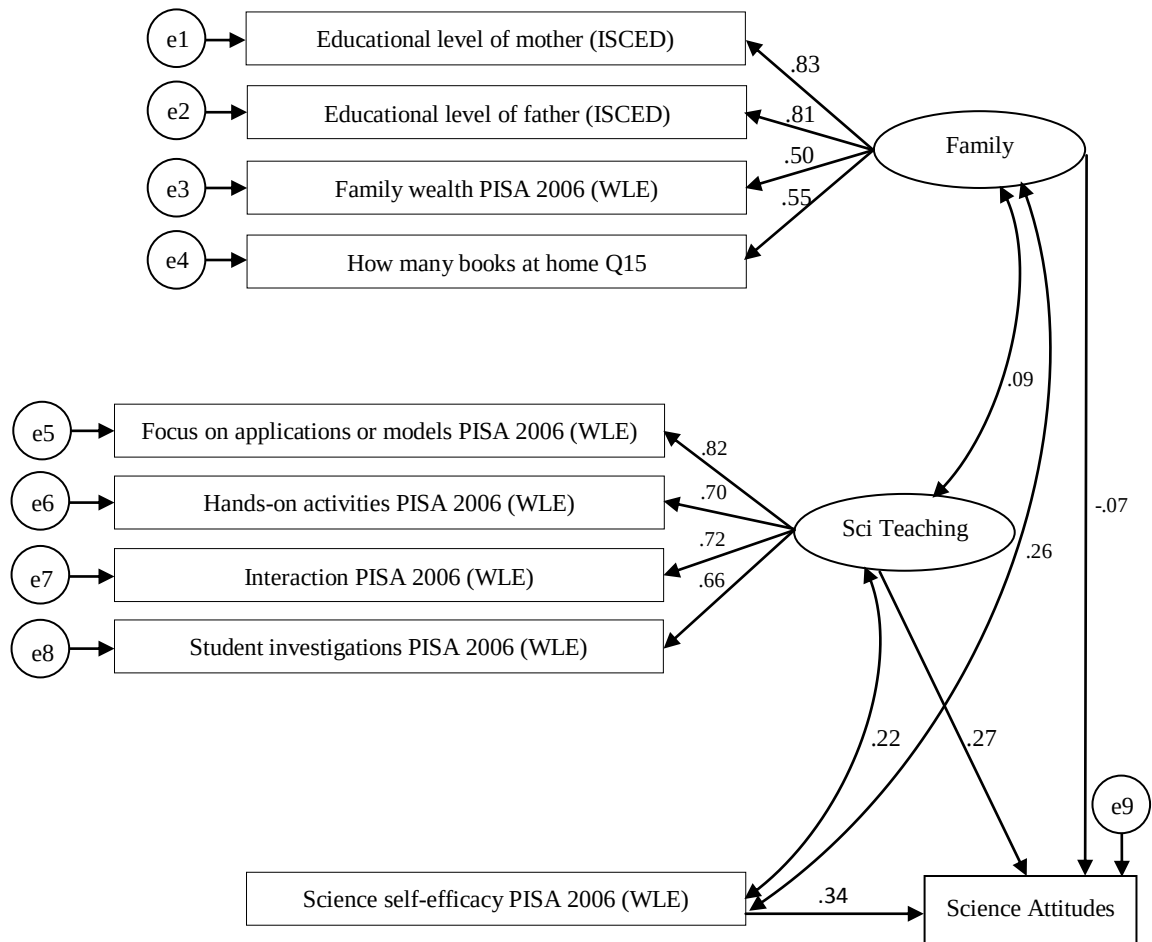


Figure 43. Model for the predictors of science attitudes for Portugal

In Portugal, science self-efficacy (0.34) is the best predictor of student's science attitudes, the second is science teaching (0.27), and the third is family background (-0.07).

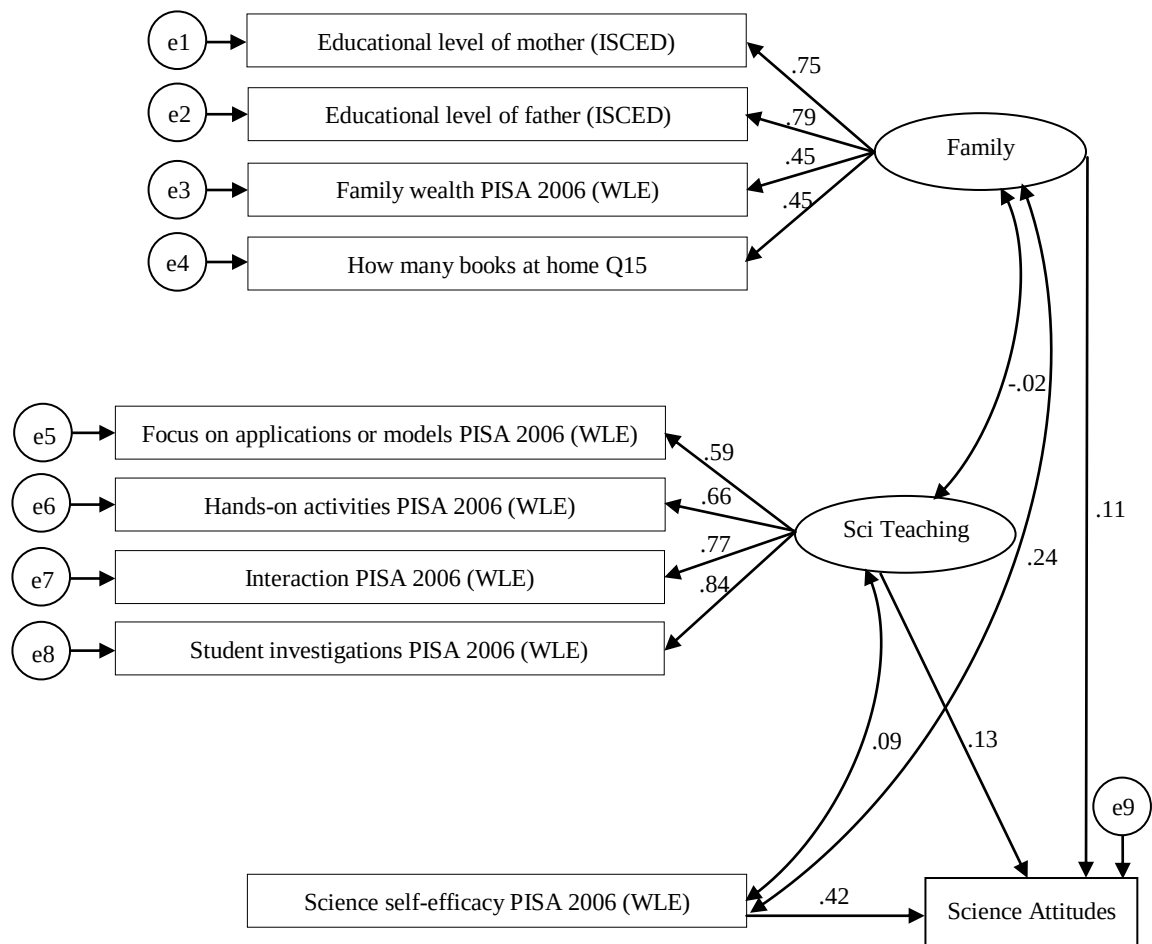


Figure 44. Model for the predictors of science attitudes for Korea

In Korea, science self-efficacy (0.42) is the best predictor of student's science attitudes, the second is science teaching (0.13), and the third is family background (0.11).

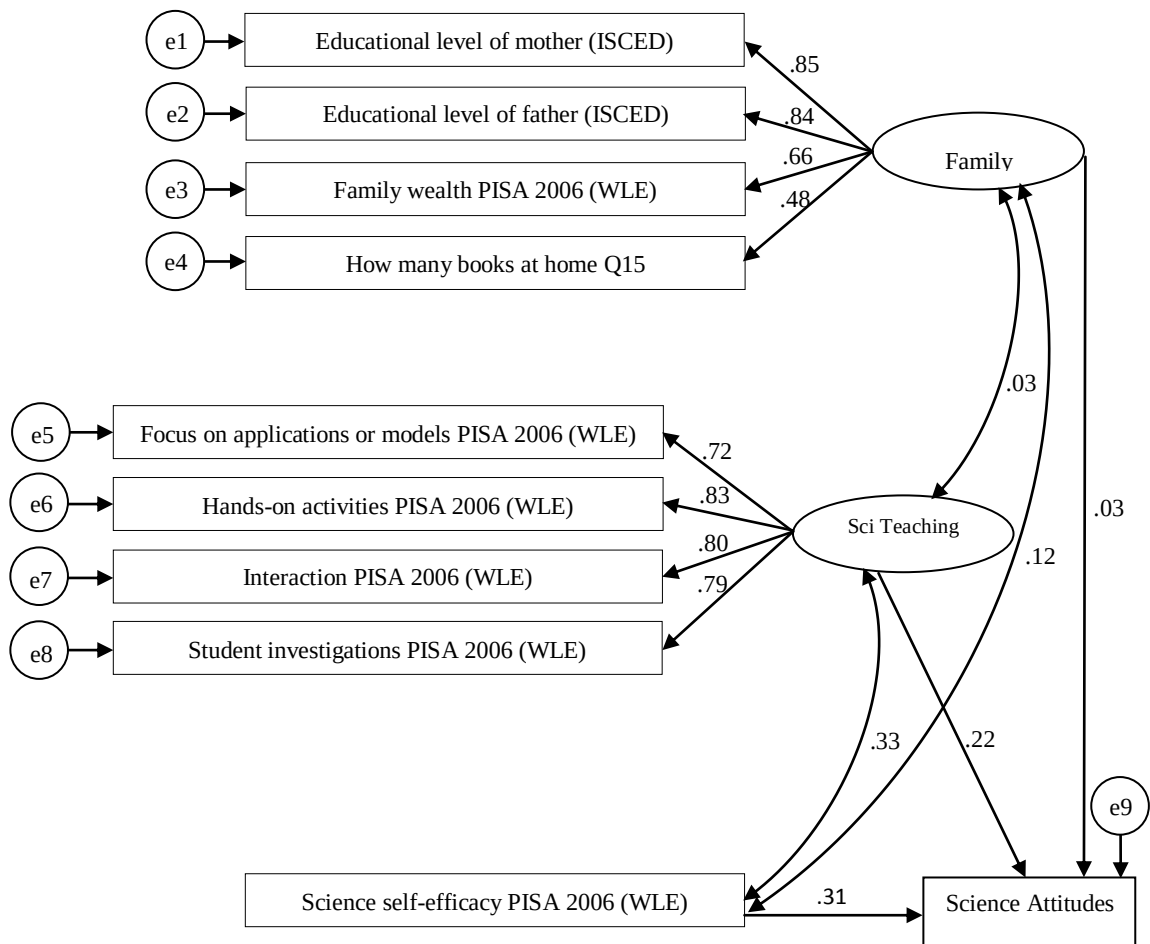


Figure 45. Model for the predictors of science attitudes for Thailand

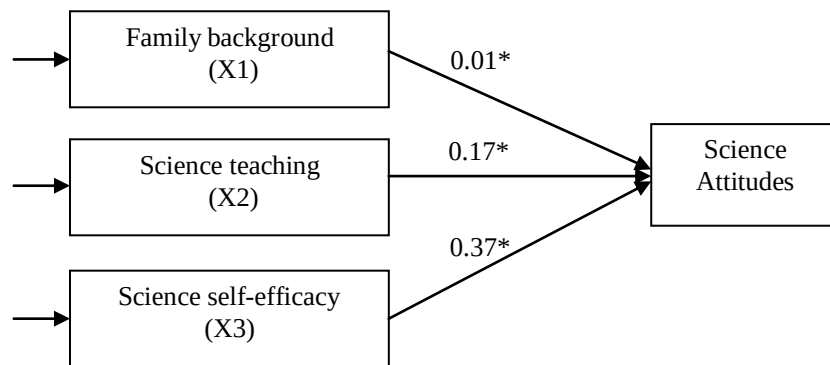
In Thailand, science self-efficacy (0.31) is the best predictor of student's science attitudes, the second is science teaching (0.22), and the third is family background (0.03). It is noteworthy that the pattern of predictors is very similar across countries.

Table 31. Results of Multiple Group Analysis of science attitudes for four countries

Variables	β_{Belgium}	β_{Portugal}	β_{Korea}	β_{Thailand}
Family background	0.01	-0.07	0.11	0.03
Science Teaching	0.17	0.27	0.13	0.22
Science self-efficacy	0.37	0.34	0.42	0.31
CFI = .949, RMSEA= .033 [C.I. 90% for RMSEA = .032, .034]				
Chi-square = 3019.060, df = 124, p-value = .000				

From Table 31 the results of Multiple Group Regression Analysis of student's science attitude by Multiple Regression Method show that the 4 variables which lead into equation by order are family background, science teaching, and science self-efficacy.

The result of analysis found that the model has Chi-square = 3019.060 ($p = .000$), $df = 124$, $CMIN/DF = 24.347$, $CFI = .949$ and $RMSEA = .033$.

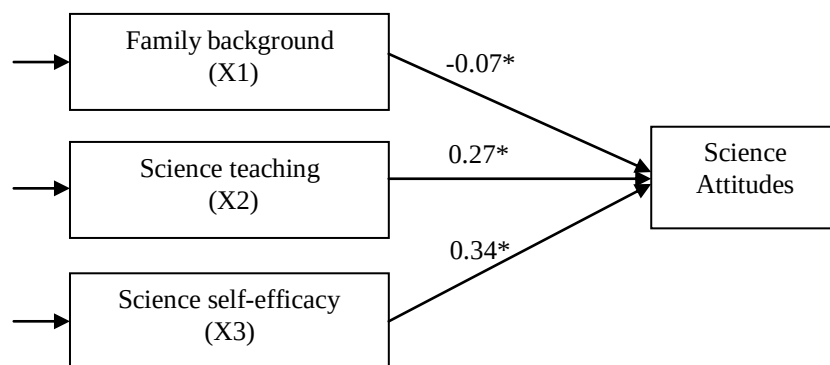


* $p < .05$

Figure 46. Multiple regression model for the predictors of science attitudes for Belgium

From the model figure 46 can make the Multiple Regression equation of standard scores to predict science attitudes for Belgium as follow:

$$Z_{Science\ Attitudes} = 0.01Z_{Family\ background} + 0.17Z_{Science\ Teaching} + 0.37Z_{Science\ self-efficacy}$$

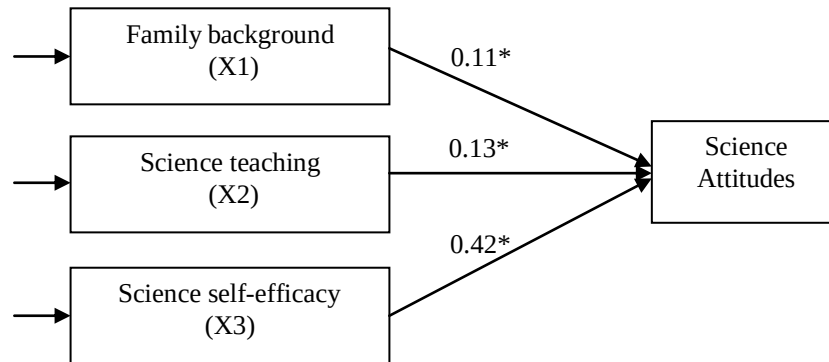


* $p < .05$

Figure 47. Multiple regression model for the predictors of science attitudes for Portugal

From the model figure 47 can make the Multiple Regression equation of standard scores to predict science attitudes for Portugal as follow:

$$Z_{Science\ Attitudes} = -0.07Z_{Family\ background} + 0.27Z_{Science\ Teaching} + 0.34Z_{Science\ self-efficacy}$$

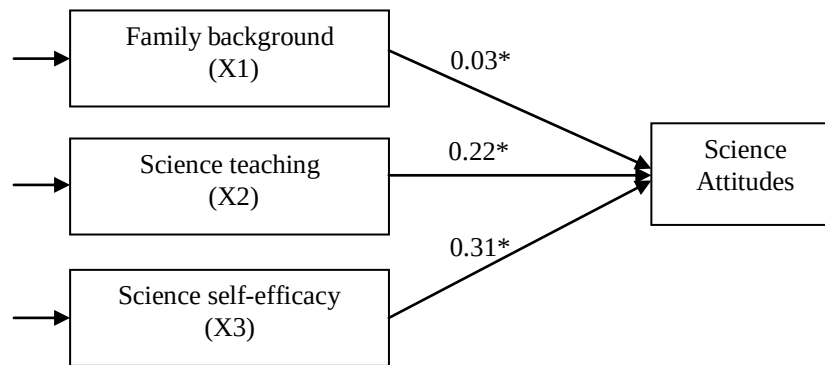


* $p < .05$

Figure 48. Multiple regression model for the predictors of science attitudes for Korea

From the model figure 48 can make the Multiple Regression equation of standard scores to predict science attitudes for Korea as follow:

$$Z_{Science\ Attitudes} = 0.11Z_{Family\ background} + 0.13Z_{Science\ Teaching} + 0.42Z_{Science\ self-efficacy}$$



* $p < .05$

Figure 49. Multiple regression model for the predictors of science attitudes for Thailand

From the model figure 49 can make the Multiple Regression equation of standard scores to predict science attitudes for Thailand as follow:

$$Z_{Science\ Attitudes} = 0.03Z_{Family\ background} + 0.22Z_{Science\ Teaching} + 0.31Z_{Science\ self-efficacy}$$

6. Conclusion

This chapter comprised the detailed report of the science knowledge and attitude analysis for the four participating countries. Firstly, mean and standard deviation of gender, grade, and books at home were analyzed for each country. The results showed that science knowledge score of both male and female in high achievers (Belgium and Korea) is very high. On the other hand, science attitude score is very high in low achievers (Portugal and Thailand). Taking grade and books at home into consideration, high achievers have higher mean total than low achievers for science knowledge and attitudes. The second part investigated the main and interaction effects for gender, grade and books at home. The findings suggest that all variables have a significant effect for European countries in Europe (Belgium and Portugal), but gender has no significant effect in Asian countries. In Belgium, most interaction effects are also significant. In Korea, only grade and books at home have a significant effect on science knowledge. In Thailand, grade, books at home, gender*grade and grade*books at home have a significant effect on science knowledge, but only grade has a significant on science attitudes. The fourth part presented the results of a set of predictors for science knowledge and attitudes. The explained variance for science knowledge is higher in Europe than Asia. Also, student characteristics have a stronger impact in Europe than in Asia. However, the impact for science attitudes is not significantly different between European and Asian countries. Finally, we performed a multiple group analysis to explore the invariance of predictors of science knowledge and attitudes. In

Belgium and Portugal, grade is the best predictor of science knowledge but in Korea it is science self-efficacy and in Thailand family background. In all countries, science teaching has a negative impact on science knowledge. There are clearly some similarities regarding predictors of science attitudes – in all countries, science self-efficacy is the best predictor of science attitudes, and science teaching plays a positive role.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the significant result and presents conclusions. The limitations of the study will be outlined. Recommendations for cross-cultural comparative studies and future research will be suggested at the end of this chapter.

This study is a cross-cultural study performing a secondary analysis of PISA2006 database involving two European and two Asian countries that differ regarding their level of results in scientific literacy: “high - achievers” (Belgium and Korea) and “low - achievers” (Portugal and Thailand). The purpose of this study was to investigate and compare the predictors of attitudes and knowledge of students. PISA 2006 assessed the development of science knowledge and skills with the goal to verify whether those were adequate for student in order to use science knowledge and skills in their real life situations. The assessment also included scientific competency, basic understanding, the ability to confront science-related problem, and student’s attitudes towards science.

In this study, the focused variables included: 1) Student characteristics: gender, grade and age of student; 2) Family background: Educational level of parents, family wealth, cultural possessions at home and number of books at home; 3) Teaching of science: Science teaching-focus on applications or models, science

teaching-hands on activities, science teaching-interaction, and science teaching-student investigation; 4) ICT: ICT Internet/entertainment use and ICT program/software use, and 5) Enjoyment of science and science self-efficacy. In the science knowledge assessment, all five variables were considered. Regarding the analysis of science attitudes, all five variables were taken into consideration as well except the variable “enjoyment of science” that is, in itself, included in science attitudes.

In this research, the most important results are outlined below:

- (i) This set of predictors of students’ science knowledge explain a high degree of variance, but higher in European countries than in Asian countries.
- (ii) In European countries, student characteristics (gender, grade, age of student) play a very crucial role in explaining differences of scientific knowledge, while in Asian countries the percentage of variance explained by these variables is less relevant; Grade is the best predictor for both Belgium and Portugal. Grade is also a relevant predictor in Korea and Thailand, but clearly less relevant than in Europe.
- (iii) Gender differences in science gained more and more attention today, as social and professional differences between men and women tend to be diluted in many countries, and gender equality is pressed as an increasingly desirable goal – including opportunities

to learn things, especially science and technology as it has been recognized that science and technology are important factors for economic and social development. A number of interesting researches about gender differences showed that male student have higher level of science and mathematics knowledge and skill than female student (Comber & Keeves, 1973; Keeves & Kotte, 1996) – an inequality between most likely caused by social and cultural factors. Overall, the results of PISA 2006 showed gender differences are the smallest in scientific knowledge, as compared to other domains, and in most countries “there is no significant difference in the average score for males and females” (OECD, 2007, p.114). In our study, gender has a significant effect on science knowledge for both Belgium and Portugal, but not on Asian countries.

- (iv) In Asian countries, family background (educational level of mother and father, family wealth, cultural possessions at home, and number of books at home) is a strong predicting variable, especially in Thailand. Previous research stressed that family background played a strong influence in student achievement (Dumas & Lambert, 2005; Marks, 2006; Willms, 2006; Marks, 2008), including variables such as family size, family type, socioeconomic background, educational level of parents, and parental occupation. There is also a distinct connection between achievement and socio-

economic status. It is often shown in the studies of many researchers that student efficiency is directly influenced by socio-economic indicators (family income, parental education) (Turmo, 2004; Sirin, 2005). Teachman (1987) found that when we considered all the factors which effected to result but the level of educational resources was related to results in achievement tests. However, educational level of parents more effect on test scores than family income (Ganzach, 2000). In Marks's study, the findings after analyzing PISA database showed that students performed better when they have positive socio-economic and cultural factors (Marks, 2006).

- (v) Science teaching showed a relation to students' science knowledge, but curiously a negative one in all countries. Quite the opposite, science teaching is positively related with science attitudes. This can be related to the type of science knowledge considered in PISA, more related to the practical application of knowledge – according to Bybee et al. (2008) the purpose of science teaching “should facilitate students' learning about science and technology as they need to understand and use them in their personal lives and as future citizens” (p. 3). But undoubtedly, this result deserves a deeper analysis in future research.
- (vi) PISA 2006 also conducted a survey focusing on the students' attitudes towards science and studied the relation between

student attitudes and scientific literacy. Attitude towards science is considered very important regarding to students' scientific literacy. The studies by Osborne and Collins (2001) pointed out that students will pay more attention to science that directly relate to their personal lives and have less interest to science that are not really relate to them. In our study, the relationship between science attitudes (interest and support for scientific enquiry) and knowledge is fable and negative, but science self-efficacy is consistently a strong predictor of science knowledge across countries and cultures.

- (vii) Our results revealed that, in both European and Asian countries, predictors of students' science attitude explain a similar degree of variance. Student characteristics variables have the least impact in students' attitudes in both European and Asian countries. Contrary to science knowledge, science teaching is important to develop science attitudes: as OECD (2007) states, "attitudes can be strongly influenced by students' peers in the classroom, the culture of their school, their home and family culture, and more generally their national culture" (p.125). Finally, science self-efficacy is the most significant predictor of science attitudes in this sample of countries.

Given these results, we consider that there are three main implications of this study. The study reveals that in Asian countries, like Korea and Thailand, family background is a strong predicting variable. Thus, the government sector should support relevant activities that stress the involvement of families in the educational process. For instance, educational policies and regulations should encourage parents, independently of their cultural background, to pay more attention to their children/students towards academic-related activities.

According to this research, the variable number of books at home is one of the significant factors that have an impact in science knowledge in all sample countries (Belgium, Portugal, Korea and Thailand). It is necessary to take this factor into consideration seriously because it appear to have high potential to increase students' learning. Due to the fact that we live in an era of high technology and computer, people might overlook the importance of books. Governments worldwide should critically pay attention to this issue, as family cultural resources make a significant difference – and schools probably need more efforts to compensate cultural disadvantages students bring to school.

Finally, one of the most important predicting variables in attitude is science self-efficacy. A model that will work best for students in order to improve their self-efficacy is peer modeling (Schunk & Hanson, 1989). Students should be in the environment surrounding by positive and highly motivated role models. With that being said, students will try to increase their self-efficacy to be the same level as others (Margolis & McCabe, 2006).

Nevertheless, this research has relevant limitations. Firstly, it is a cross-cultural study between two regions: Europe and Asia, and we did not perform an in-depth analysis of the cultural and educational conditions that might help us better understand some of the results. The dimension of the samples in each country is also varied: Belgium assessed 8,857 students which is almost double of sample number in Portugal (5,109 students) and Korea (5,176 students). Thailand's sample involved 6,192 students.

Moreover, the data emerged solely from PISA 2006, which emphasized on science knowledge and attitudes – and we took the dimensions as they were conceptualized by PISA, admitting that the vision of science literacy is one among many, and the same could be said regarding the way it was operationalized in the questionnaires.

Finally, two sample countries from each continent were selected: Europe (Belgium and Portugal), and Asia (Korea and Thailand). Our results show interesting cross-cultural variations, namely that science knowledge was influenced by student characteristics in European countries while family background variables were especially relevant in Asian countries. However, results cannot be generalized to all European and Asian countries, since there are only two sample countries from each continent.

On the whole, our research shows that, in order to effectively develop scientific knowledge, contextual variables are extremely important. Consequently, instead of having a “global model” for predictors of scientific knowledge and

attitudes, it is necessary to look deeper into cultural and contextual influences to explain variances in scientific literacy. We hope that, in the future, this trend of comparative studies research will be furthered, thus allowing for a more complex and deep understanding of the factors that explain student learning across the world.

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APPENDIX

Predictors of Attitudes and Knowledge of Students in PISA 2006: A Comparison between Europe and Asia

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Abstract

This paper examined the relative influence of students' characteristics, family background, school characteristics and cultural context in the attitudes and knowledge about science in Europe and Asia, using the OECD's 2006 Programme for International Student Assessment (PISA). We used data from two European and Asian countries that differ regarding their level of PISA results; "high-achievers" (Belgium N = 8,857 and Korea N = 5,176) and "low-achievers" (Portugal N = 5,109 and Thailand N = 6,192). Results showed variations in the sets of predictors that explain the differences of attitudes and knowledge of 15 year old students about science. European and Asian countries have specific cultural characteristics which apparently are educationally relevant and account for a strong variation of the results.

Keywords: *Student attitudes, Student knowledge, Cross-cultural differences, Scientific literacy, Secondary analysis*

Introduction

In contemporary societies, science is relevant to everyone's life, so an understanding of science is an essential tool. This is why educational reform agendas focus on scientific literacy as an important goal to be achieved (Lee & Fradd, 1996; OECD, 2006).

Attitudes and interests established in early childhood play an

important role on lifelong scientific literacy (Schroeder et al, 2009); empirical studies show positive and significant relationships between formal scientific knowledge and attitudes toward science (Sturgis & Allum, 2004; Bybee, 2008). However, there is no significant difference between gender and science performance (Mark, 2008); additionally, scientific interest is strongly related to family background, particularly parental education, income, and young adults' socioeconomic outcomes (Sandefur et al, 2005; Settersten et al, 2005). Therefore, the aims of this study were to expand existing research by investigating and comparing the relative influence of students' characteristics, family background and school characteristic on the attitudes and knowledge about science in two different cultural contexts: Europe and Asia.

Methodology

This study uses the OECD's 2006 Programme for International Student Assessment (PISA) data. PISA is a well known database to investigate student achievement of more than 400,000 15-year-old students from 57 countries; in this cross-cultural study we used data from two European and two Asian countries that differ regarding their level of PISA results; "high-achievers" (Belgium N = 8,857 and Korea N = 5,176) and "low-achievers" (Portugal N = 5,109 and Thailand N = 6,192); our goal is to perform a secondary analysis to investigate and compare the predictors of attitudes and knowledge in science.

Results

Multiple regression analysis of predictors for attitudes and knowledge among European and Asian countries are presented in Table 1 for Adjusted R Square Multiple Regression and Table 2 for Standardized Regression Coefficients. Results reveal that student characteristics are particularly relevant in predicting knowledge in European countries, whereas family background seems to be most relevant in Asian countries. Positive attitudes towards science seem to be highly dependant, in both cultural contexts, from student's scientific interest and self-efficacy, and therefore appear to be less affected by cultural diversity.

Conclusions

Four major conclusions can be drawn from this study:

1. This set of predictors of students' knowledge explains a high degree of variance, but the degree in European countries (Belgium

Table1 Adjusted R Square Multiple Regression of predictors for attitudes and knowledge among European and Asian countries

Models	Europe				Asia			
	Attitudes (Adjusted R Square)		Knowledge (Adjusted R Square)		Attitudes (Adjusted R Square)		Knowledge (Adjusted R Square)	
	Belgium (high)	Portugal (low)	Belgium (high)	Portugal (low)	Korea (high)	Thailand (low)	Korea (high)	Thailand (low)
1. Student characteristics	.002	.004	.285	.483	.007	.014	.008	.148
2. Student characteristics and Family background	.042	.021	.373	.525	.074	.032	.178	.318
3. Student characteristics, Family background and Teaching of science	.093	.127	.478	.566	.130	.143	.266	.340
4. Student characteristics, Family background, Teaching of science and ICT	.103	.138	.479	.570	.142	.143	.274	.367
5. Student characteristics, Family background, Teaching of science, ICT and Interest / Self-efficacy	.357	.333	.542	.630	.333	.318	.396	.403

Table2 Standardized Regression Coefficients of attitudes and knowledge among European and Asian countries

Variables	Europe								Asia							
	Attitudes				Knowledge				Attitudes				Knowledge			
	Belgium (high)	Portugal (low)	Belgium (high)	Portugal (low)	Belgium (high)	Portugal (low)	Belgium (high)	Portugal (low)	Korea (high)	Thailand (low)	Korea (high)	Thailand (low)	Korea (high)	Thailand (low)	Korea (high)	Thailand (low)
	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)	Beta (β)	Sig. (p)
- Gender	.007	.491	-.044	.002*	-.061	.000*	-.111	.000*	-.027	.030*	.050	.000*	-.009	.437	.033	.002*
- Grade	-.034	.002*	-.007	.663	.352	.000*	.537	.000*	.001	.915	.074	.000*	.045	.000*	.241	.000*
- Age of student	.027	.006*	.019	.171	-.018	.030*	-.046	.000*	.045	.000*	-.019	.106	.052	.000*	-.009	.424
- Educational level of mother	-.015	.194	-.008	.690	.058	.000*	.056	.000*	.006	.678	.017	.310	.013	.369	.086	.000*
- Educational level of father	-.002	.862	-.045	.018*	.030	.002*	.005	.725	.023	.138	.003	.847	.062	.000*	.144	.000*
- Family wealth PISA 2006	-.037	.000*	-.038	.019*	.014	.123	.007	.541	.039	.003*	-.017	.241	-.015	.237	.150	.000*
- Cultural possessions at home	.045	.000*	.026	.126	.048	.000*	.026	.038*	.057	.000*	-.006	.615	.097	.000*	.001	.906
- How many book at home	.003	.811	-.026	.142	.135	.000*	.108	.000*	-.004	.740	.023	.062	.176	.000*	.130	.000*
- Science Teaching-Focus on applications or models	.069	.000*	.176	.000*	.148	.000*	.092	.000*	.136	.000*	.184	.000*	.166	.000*	.104	.000*
- Science Teaching-Hands on activities	-.056	.000*	.003	.864	.106	.000*	.022	.091	.035	.017*	.018	.283	.008	.586	.037	.016*
- Science Teaching-Interaction	.046	.000*	.013	.459	-.084	.000*	-.060	.000*	.018	.266	-.001	.957	-.138	.000*	-.081	.000*
- Science Teaching-Student investigations	.042	.001*	-.005	.786	-.295	.000*	-.196	.000*	-.038	.027*	-.010	.520	-.206	.000*	-.108	.000*
- ICT Internet/entertainment use	-.042	.000*	-.028	.108*	.030	.003*	.015	.234	.005	.716	.007	.655	-.070	.000*	.094	.000*
- ICT Program/software use	.048	.000*	.077	.000*	-.073	.000*	-.096	.000*	.028	.044*	-.008	.598	-.006	.642	-.234	.000*
- Science self-efficacy	.184	.000*	.192	.000*	.198	.000*	.146	.000*	.258	.000*	.196	.000*	.181	.000*	.077	.000*
- Enjoyment of science	.451	.000*	.372	.000*	.126	.000*	.174	.000*	.310	.000*	.334	.000*	.270	.000*	.164	.000*

* $p < .05$

= 54.2%, Portugal = 63.0%) is higher than in Asian countries (Korea = 39.6%, Thailand = 40.3%), independently of their status as “low” and “high-achievers”.

2. In European countries, student characteristics play a very

important role in explaining differences of knowledge (Belgium = 28.5%, Portugal = 48.5%); in Asian countries, the percentage of variance explained by these variables is less relevant (Korea = 0.8%, Thailand = 14.8%). However, in both regions, age, gender and grade are more significant in countries where the level of knowledge is lower.

3. In Asian countries, family background is the strongest predicting variable. However, there are significant differences in the specific variables that account for the differences - suggesting that contextual variables are playing an important role in the development of scientific knowledge.

4. This set of predictors of students' attitudes explains a similar degree of variance for both European and Asian countries (Belgium = 55.7%, Portugal = 55.3%, Korea = 55.3% and Thailand = 51.8%).

This study suggests that exploring predictors of knowledge and attitudes in the scientific domain should be taking into account cultural and contextual influences, rather than generating a "global" model. Further research is necessary to understand the role of cultural and contextual variables in scientific literacy, as this appears to be a road less traveled but certainly worth exploring.

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