Utilizing Data from International Achievement Studies in Teacher Professional Development in Science

Elena Papanastasiou[1] and Maria Evagorou[2]

Abstract

Cypriot students have consistently scored low in science in international studies since 1995 despite various curriculum reform efforts during the last decades. Given the importance of teacher professional development, and the opportunity to further utilize data from an international study, the purpose of this paper is to show how data from the Trends in International Mathematics and Science Study (TIMSS) can be used for a professional development workshop focused on helping teachers identify reasons for low achievement in science, and proposing ways to support students in science. Overall, this professional development workshop could be considered as an effective way of using empirical data from international studies for professional development purposes as it gave teachers the opportunity to reflect on possible reasons that Cypriot students did not do well on certain items while allowing them to make connections between their teaching practice and student content knowledge misconceptions.

Keywords: professional development, Trends in International Mathematics and Science Study (TIMSS), international studies, science education, science achievement

Introduction

The growing importance of science and science education worldwide is clearly evident in the emphasis placed on these subjects in developed countries,[3] as well as through their links with a country's human capital. A country's human capital is often determined by the quality of schooling, which, according to Woessmann,[4] is measured by students' performance on cognitive achievement tests. These cognitive achievement tests have shown to exert an impact on the level of economic development,[5] and for Cyprus these measures, especially in science and mathematics, have been consistently

1 Elena Papanastasiou is Associate Dean in the School of Education, at the University of Nicosia.

2 Maria Evagorou is Associate Professor in the School of Education, at the University of Nicosia.

3 National Research Council. *Taking Science to School: Learning and Teaching Science in Grades K-8*. (Washington, DC: The National Academies Press, 2007), DOI.org/10.17226/11625.

4 L. Woessmann, 'Central Exit Exams and Student Achievement: International Evidence', in, *No Child Left Behind? The Politics and Practice of School Accountability.* eds P. E. Peterson and M. R. West (Washington, D.C.: Brookings Institution Press, 2003).

5 E. Hanushek and D. Kimko, 'Schooling, Labor-Force Quality and the Growth of Nations'. *American Economic Review,* Vol. 90, No. 5 (2000),1184–1208; L. Woessmann, 'Growth, Human Capital and the Quality of Schools: Lessons from International Empirical Research', *Strategies for Employment and Growth in Austria*, Vol. 10, (2006), 74-98.

low during the last decades.[6]

Very often student outcomes are linked to the quality of teacher professional development within a country.[7] Because of this link, countries across the world have applied various professional development methods to improve science teaching and consequently student outcomes.[8] Therefore, current professional development programmes place an emphasis on teachers' pedagogical knowledge and skills and also on making the connection between teaching and learning.[9] However, despite the changes in teacher professional development in science education within Europe, recent EU reports[10] still point out that the number of students choosing science as a field of study is declining and that the quality of science education in terms of relative attainment and scores are lower than expected in a number of countries, including Cyprus.[11]

Cypriot students have consistently scored low in science in international studies since 1995[12] and this is especially evident with elementary and middle school students. Despite various curriculum reform efforts during the last decades,[13] most of them focusing on changing the curriculum materials without placing an emphasis on teacher professional development, assessment scores remain low. There are many discussions on why Cypriot students are not successful in international studies. However, very few researchers within Cyprus have actually utilized the data from international studies to verify whether the various assumptions made are correct.[14] Nor have the data

6 Word Bank Report, *Analysis of the Function and Structure of the Ministry of Education and Culture of the Republic of Cyprus*. (Washington, D.C.: The World Bank, 2014).

7 OECD, *PISA 2006: Science Competencies for Tomorrow's World* (Paris: OECD Publications, 2006); J. Osborne and J. Dillon, Science Education in Europe: Critical Reflections. (UK: Nuffield Foundation, 2008).

8 M. Evagorou, J. Dillon, J. Viiri, and V. Albe, 'Pre-service Science Teacher Preparation in Europe: Comparing Pre-service Teacher Preparation Programs in England, France, Finland and Cyprus'. J*ournal of Science Teacher Education*, Vol. 26, No. 1 (2015), 99–115. DOI.org/10.1007/s10972-015-9421-8.

9 M. Cochran-Smith, 'The Problem of Teacher Education'. J*ournal of Teacher Education,* Vol. *55,* No. 4 (2004), 295–299. DOI:10.1177/0022487104268057'.

10 European Commission. *Developing Key Competences at School in Europe: Challenges and Opportunities for Policy.* (Brussels: European Commission, 2012); Eurydice, *Science Education in Europe: National Policies, Practices and Research* (Brussels: Education, Audiovisual and Culture Executive Agency, 2011).

11 OECD, *PISA 2006: Science Competencies for Tomorrow's World* (Paris: OECD Publications, 2006).

12 Word Bank Report, *Analysis of the Function and Structure of the Ministry of Education and Culture of the Republic of Cyprus*. (The World Bank, 2014).

13 Ministry of Education and Culture (MOEC), *New Curriculum for the Teaching of Science.* (Nicosia: Ministry of Education and Culture, 2011).

14 E. C. Papanastasiou and M. Zembylas, Did the Cypriot students really cheat on TIMSS? *Research in Comparative and International Education, Research in Comparative and International Education,* Vol.

been utilized in the past in order to guide the creation of professional development programmes in science.

Given the importance of teacher professional development and the opportunity to use data from an international study, the purpose of this paper is to show how data from the Trends in International Mathematics and Science Study (TIMSS) can be used for a professional development workshop focused on helping teachers identify reasons for low achievement in science and proposing ways to support students in science.

Trends in International Mathematics and Science Study

The Trends in International Mathematics and Science Study (TIMSS), which is conducted by the International Association for the Evaluation of Educational Achievement (IEA), is an international assessment of the performance of fourth and eighth grade students in mathematics and science. TIMSS has been conducted every four years since 1995 and has collected comprehensive data on students' contexts of learning mathematics and science. The goal of TIMSS, as provided by the IEA, is to help countries

> make informed decisions about how to improve teaching and learning in mathematics and science. With its strong curricular focus and emphasis on policy relevant information about the home, school and classroom contexts for learning, TIMSS is a valuable tool that countries can use to evaluate achievement goals and standards and monitor students' achievement trends in an international context.[15]

In 1995, data were collected from three target populations in 45 countries. These were defined as (a) the two adjacent grades where the majority of 9-year-old students were enrolled, (b) the two adjacent grades where the majority of 13-year-old students were enrolled and (c) students in their final year of secondary education.[16] In 1999, the target population was limited to eighth grade students. From 2003 onwards, the sampling scheme includes fourth- and eighth-grade students, while in 2015, students in their last year of high school were also sampled. During the 2015 administration of TIMSS, more than 57 countries and more than 580,000 students participated in the assessment.

The selection of schools in each country is based on a two-stage random sampling design.[17] Schools are first sampled from each national school sampling frame with

1 (2006), 120-125.

15 TIMSS and PIRLS International Study Center, *About TIMSS 2015* (Chestnut Hill, MA, 2016), available at http://timss2015.org/timss-2015/about-timss-2015/.

16 M. O. Martin and D. L. Kelly (eds.), *TIMSS technical report, volume I: Design and development*. (Chestnut Hill, MA: Boston College, 1996).

17 S. LaRoche, et al., 'Sample Design in TIMSS 2015', in *Methods and Procedures in TIMSS 2015*,

probabilities that were proportional to school size (and sometimes stratified on certain demographic information), while at a second stage, intact classes are chosen through equal probability systematic random sampling.

At the elementary school level, Cyprus participated in TIMSS in 1995, 2003 and 2015. In 2015, 4343 fourth grade students from 148 schools participated in the study. The average science performance of Cyprus in 2015, at the fourth-grade level, was 481, which was below the international average of 500. This achievement was almost identical to our performance in 2003, which was 480, although in 1995 our performance was much lower (450). So, by comparing our country's results with our own performance in the past, it is evident that no progress has been made in the performance of our students in the last decade, as evident by TIMSS trends.

The Workshop

As a way to support teachers' understanding of the underlying reasons for the low scores of Cyprus in TIMSS science, a professional development workshop was created for elementary school teachers in Cyprus in 2017. According to Gess-Newsome et al.,[18] students' outcomes in science should be used as part of teacher professional development programmes as a way to empirically help teachers reflect on their teaching practices and improve them. However, such data are not always available to teachers, which is the case in Cyprus, and therefore, using data from TIMSS had provided a unique opportunity for this workshop. Furthermore, the utilization of such data was of special significance since no other nationwide assessment takes place within Cyprus which could be used to evaluate outcomes from science education for elementary and middle school students.[19]

The workshop was collaboratively developed by academics in science education and measurement, with the support of the Ministry of Education and Culture in Cyprus (MOEC) and, more specifically, with the science inspector for elementary schools. This collaboration enabled researchers, science educators from three universities in Cyprus, curriculum developers and textbook writers to come together with the common goal of identifying the reasons for the low achievement of Cyprus in elementary school science, in an effort to support teachers to improve their practice. In a preparatory

eds. M. O. Martin, I. V. S. Mullis and M. Hooper (TIMSS and PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement, 2016), 3.1-3.37.

18 J. Gess-Newsome, et al., 'Teacher pedagogical content knowledge, practice, and student achievement', *International Journal of Science Education*, (2017) DOI: 10.1080/09500693.2016.1265158.

19 E. C. Papanastasiou and M. P. Michaelides, 'Issues of Perceived Fairness in Admissions Assessments in Small Countries: The Case of the Republic of Cyprus', in *Higher Education Admission Practices: An International Perspective*, eds. M.E. Oliveri and C. Wendler (Cambridge: Cambridge University Press, 2019).

workshop in May 2017, the aforementioned stakeholders worked together looking at TIMSS restricted-use items and responses from fourth grade Cypriot students. The discussions focused on whether the items were part of the taught curriculum, the ways in which the specific topics are typically taught and possible reasons for which Cypriot students were not successful on each specific item. The outcomes of the discussions were used as guidelines to design the main workshop targeted to elementary school teachers.

The final version of the workshop took place in January and February 2018 and was repeated in Nicosia, Limassol, Larnaca and Paphos. This was a compulsory workshop for all teachers who act as coordinators for science lessons in elementary schools, so a total of 346 teachers participated in the four workshops. Some of the teachers had experience with TIMSS as their students had participated in the study in the past. The workshop took place during school time and had a total duration of five hours.

The Structure of the Workshop

The workshop was structured around three main components: a) Introduction to TIMSS; b) Reflecting on students' responses; and c) Strategies to support students.

Introduction to TIMSS: In the first part of the workshop, elementary school teachers were presented with an overview of TIMSS to help them understand the rationale and the processes behind the study (i.e., how items are designed and piloted, links to local curricula, translation of items). A presentation of the findings of the study, with an emphasis on the performance of Cyprus in science since 1995 followed. The teachers were asked to comment on the findings based on their experiences, and after the discussion, the teachers were invited to complete an online poll regarding their beliefs for the main reasons Cypriot students did not perform well in TIMSS science. Specifically, teachers were asked to indicate the single most important reason among five possible ones for the low results of Cyprus on TIMSS. These five options were selected based on what we already know from the literature[20] and the discussions taking place in Cyprus regarding students' low achievement. The reasons included in the poll were: lack of skills in answering multiple-choice questions, difficulties in reading instructions, difficult language/terminology in the questions, lack of motivation, and lack of content knowledge. The outcomes of the online poll were not presented to the teachers at this point, but were used in the third part of the workshop to compare the teachers' initial views and how these might change after engaging with and discussing

20 A. Cavagnetto, et al., 'The Nature of Elementary Student Science Discourse in the Context of the Science Writing Heuristic Approach'. *International Journal of Science Education*, Vol. 32, No. 4 (2015), 427–449, DOI: 10.1080/09500690802627277; J. Wellington and J. Osborne, *Language and Literacy in Science Education* (Buckingham, UK: Open University Press/McGraw-Hill International, 2001).

each restricted use item along with their results.

Reflecting on students' responses: In the second part of the workshops, teachers were assigned to groups and were provided with released and restricted use items from TIMSS. TIMSS items are divided in categories of content domains (Life Science, Physical Science, Earth Science) and by cognitive levels (knowing, applying, reasoning), so this information was available for the teachers. Each group focused on different questions. Furthermore, along with each item, the teachers were given the percentage of correct responses of the Cypriot students, as well as the international percentage of correct responses. Each group was led by two moderators: a science curriculum developer, who was involved in the development of teaching materials, and a science educator. The curriculum developers provided the following information about each of the items: whether the content on which the item was based was included in the local curriculum, in which grade and the context in which it was presented to the students. Figures 1 and 2 provide examples of how the items were presented to the teachers.

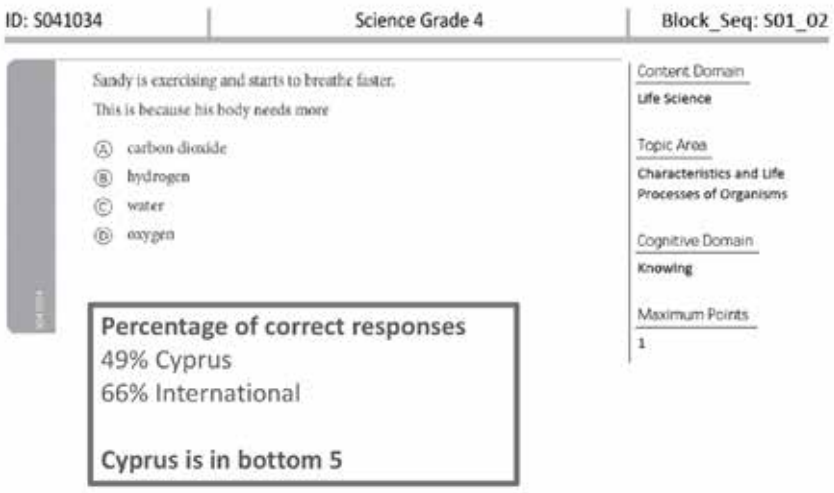

Figure 1: Example of a TIMSS released item that was presented at the workshop

When applicable, a note was made on whether Cypriot students' performance was in the ten top or bottom countries in terms of percentage of correct scores. Each item was presented to the whole group and the moderators asked the participants to reflect on the question and the percentage of correct responses. Based on the provided information and their experience in class, teachers were asked to explain the performance of Cypriot students for each item by commenting on the taught curriculum, possible misconceptions or other reasons for which students could not

identify the correct response. The discussion was recorded by one of the moderators, and at the end of the group work, an overview of the possible reasons for the low science scores in Cyprus was summarized to be presented to the other groups.

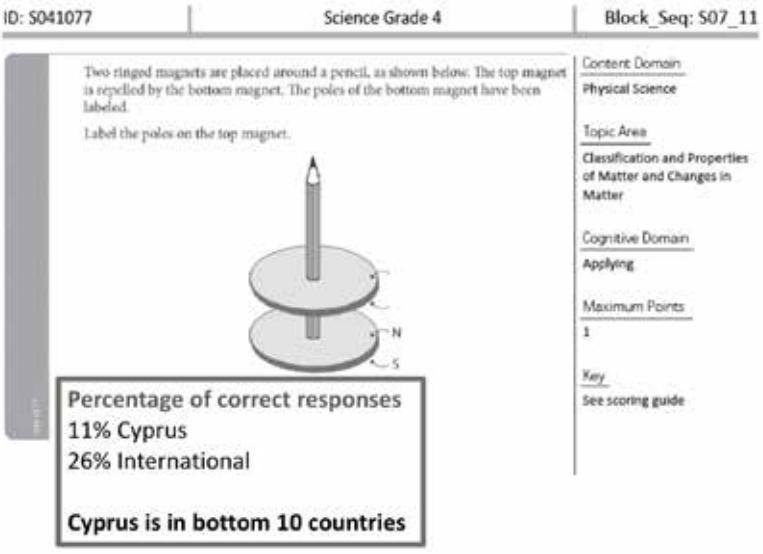

Figure 2: Example of a TIMSS released item that was presented at the workshop

Strategies to support students: In the third part of the workshop teachers returned to the whole group to discuss the findings from the group work. The last part of the workshop was designed in a way to emphasize teaching practices to support elementary school students to improve their reading, writing and oral skills,[21] as well as their skills in answering multiple choice questions.[22] At the end of the workshop, the teachers were asked to reflect on their needs in terms of professional development, with the majority of the teachers reporting the need to participate in communities of practice with other teachers and to participate in professional development on how to support language skills in science.

21 M. Evagorou and J. Osborne, 'The role of language in the learning and teaching of science', in *Good Practice in Science Teaching*, 2nd ed., eds. J. Osborne and J. Dillon (New York, NY: Open University Press/McGraw Hill, 2010), 135–157; K. L. McNeill and J. Krajcik, S*upporting grade 5-8 students in constructing explanations in science: The claim, evidence and reasoning framework for talk and writing* (New York, NY: Pearson, 2012).

22 C. Dignath, et al., 'How can primary school students learn self-regulated learning strategies most effectively?: A meta-analysis on self-regulation training programmes'. *Educational Research Review*, Vol. 3, No. 2 (2008), 101–129, DOI: 10.1016/j.edurev.2008.02.003.

Results

In the first part of the workshop, a poll took place among the workshop participants in order to gather their pre-existing views on the reasons why the performance of the Cypriot elementary school students in TIMSS science was inadequate. According to the results of the poll, the reason that was selected by the majority of the teachers (35%) was the student's difficulty in reading the instructions for the test items. The second most frequently selected reason (25%) was that these students did not have a lot of skills in answering such tests. Twenty-two percent of the participants indicated that the terminology that was used in the science items was the reason why Cypriot students did not do well. Finally, 11% indicated that the students did not have enough motivation to do well on the test, while 6% indicated that the low results were from a lack of science content knowledge.

At a later stage of the workshop, the qualitative descriptions of the discussions that took place were summarized, while emphasizing the variety of reasons that were used to explain the performance of the Cyprus students on each item. Based on this summary, a number of distinct patterns emerged. First of all, the wording of specific items was a significant factor that could explain part of the performance of students in Cyprus. In some cases, for example, the terminology that was used for certain items was more scientific and differed from the everyday terminology that is typically used by the students. As a result, this more unfamiliar terminology might have been one factor that could potentially explain the unsatisfactory results on some test items. In addition to problems with terminology, the students also tended to have difficulties in reading and comprehending text intensive items that were quite lengthy. Therefore, students from Cyprus were either not able to properly comprehend these items, or were less likely to make an effort to read and answer them correctly.

A second and very important finding from the workshop verified the fact that Cypriot students tended to do better on the items that included scenarios that were closer to their everyday experiences. For example, because of Cyprus' climate, students appeared to be very knowledgeable of how to protect themselves and their skin from the sun and performed quite well on items related to this issue. The positive results on the items related to their experiences were found even with items whose content was not included in the science curriculum up to the fourth grade and thus were never taught in the classroom. Moreover, as expected, Cypriot students did less well on items with content that was not related to their experiences or the local context (e.g., items about fossils).

Conclusion

Overall, this professional development workshop could be considered as an effective way of using empirical data from international studies for professional development purposes. This was especially important for Cyprus, as no other large-scale standardized testing data are available for such purposes for elementary school students.

Some effective components of this professional development workshop were the following: First of all, the presentation of the restricted-use items along with the percentage of correct responses from Cyprus drew the teacher's attention to the main building block of these assessments (the items) and away from discussions on the usefulness of league tables and a country's rank. This also gave them the opportunity to reflect on possible reasons why our students did not do well on certain items, while allowing them to make connections between their teaching practice and student content knowledge misconceptions. Specifically, the teachers highlighted difficulties with language skills and lack of experiences as important reasons for students' low achievement. Researchers in science education have repeatedly highlighted these reasons in the past,[23] but according to the teachers the local science curricula does not place an emphasis on these aspects of science, especially the aspect of language and terminology. Moreover, the participation of all education-related stakeholders in these workshop discussions led to fruitful exchanges among all participants, who all had a common goal in mind: the improvement of the quality of science education within Cyprus.

Finally, the detailed briefing about the design and development of the TIMSS items clarified many of the teachers' misunderstandings in regard to such studies and enabled them to better understand such studies. For example, most of the teachers were not aware that some TIMSS items are also written by educators in Cyprus or that the test items do not perfectly match the curriculum of any specific participating country.

Since TIMSS also has a mathematics component, and since Cyprus has participated in other international studies in the past (e.g., in the Progress in International Literacy Study (PIRLS)), this model could be replicated in other subject matters, too. Through the collaboration of all relevant stakeholders, and by utilizing the freely available data provided by these international studies, we are confident that significant progress can be made in the educational system of Cyprus in terms of learning outcomes with the ultimate goal of providing a better future for our students.

23 A. Cavagnetto, B. M. Hand and L. Norton Meier, 'The Nature of Elementary Student Science Discourse in the Context of the Science Writing Heuristic Approach' *International Journal of Science Education*, Vol. 32, No. 4 (2015); Wellington and Osborne, *Language and Literacy in Science Education*.

References

Cavagnetto, A., Hand, B. M. and Norton Meier, L. (2015) 'The Nature of Elementary Student Science Discourse in the Context of the Science Writing Heuristic Approach'. *International Journal of Science Education*, Vol. *32,* No. 4: 427–449. Available at DOI: 10.1080/09500690802627277.

Cochran-Smith, M. (2004) 'The Problem of Teacher Education'. J*ournal of Teacher Education,* Vol. *55,* No. 4: 295–299. Available at DOI:10.1177/0022487104268057'.

Dignath, C., Buettner, G. and Langfeldt, H.-P. (2008) 'How can primary school students learn self-regulated learning strategies most effectively?: A meta-analysis on self-regulation training programmes'. *Educational Research Review*, Vol. 3, No. 2: 101–129. Available at DOI: 10.1016/j.edurev.2008.02.003.

European Commission (2012) *Developing Key Competences at School in Europe: Challenges and Opportunities for Policy.* European Commission.

Eurydice (2011) *Science Education in Europe: National Policies, Practices and Research. Education*. Brussels: Audiovisual and Culture Executive Agency.

Evagorou, M., Dillon, J., Viiri, J. and Albe, V. (2015) 'Pre-service Science Teacher Preparation in Europe: Comparing Pre-service Teacher Preparation Programs in England, France, Finland and Cyprus'. *Journal of Science Teacher Education*, Vol. 26*,* No. 1, 99–115. Available at DOI: 10.1007/s10972-015-9421-8.

Evagorou, M., and Osborne, J. (2010) 'The role of language in the learning and teaching of science'. In J. Osborne & J. Dillon (Eds), *Good Practice in Science Teaching*, 2nd ed., Berkshire: Open University Press: 135–157.

Gess-Newsome, J., Taylor, J., Carlson, J., Gardner, A. Wilson, Ch. and Stuhlsatz, M. (2017) 'Teacher pedagogical content knowledge, practice, and student achievement', *International Journal of Science Education*, DOI: 10.1080/09500693.2016.1265158.

Hanushek, E. and Kimko D. (2000) 'Schooling, Labor-Force Quality and the Growth of Nations'. *American Economic Review,* Vol. 90*,* No. 5: 1184–1208.

LaRoche, S., Joncas, M. and Foy, P. (2016) 'Sample Design in TIMSS 2015'. In M. O. Martin, I. V. S. Mullis and M. Hooper (eds), *Methods and Procedures in TIMSS 2015*. Chestnut Hill, MA: TIMSS and PIRLS International Study Center: 3.1-3.37.

Martin, M.O. and Kelly, D.L. (eds). (1996) *TIMSS technical report: Design and Development,* Vol. I. Chestnut Hill, MA: Boston College.

McNeill, K. L. and Krajcik, J. (2012) S*upporting grade 5-8 students in constructing explanations in science: The claim, evidence and reasoning framework for talk and writing*. New York, NY: Pearson.

Ministry of Education and Culture (MOEC) (2011) *New Curriculum for the Teaching of Science*. Nicosia: Ministry of Education and Culture.

National Research Council. (2007) *Taking Science to School: Learning and Teaching Science in Grades K-8*. Washington, DC: The National Academies Press. DOI: 10.17226/11625.

Organisation of Economic Cooperation and Development (2006) *PISA 2006: Science*

Competencies for Tomorrow's World. Paris: OECD Publications.

Osborne, J. and Dillon, J. (2008) *Science Education in Europe: Critical Reflections*. London: Nuffield Foundation.

Papanastasiou, E. C. and Michaelides, M. P. (2019) 'Issues of Perceived Fairness in Admissions Assessments in Small Countries. The Case of the Republic of Cyprus'. In M.E. Oliveri and C. Wendler (Eds.), *Higher Education Admission Practices: An International Perspective*. Cambridge: Cambridge University Press.

Papanastasiou, E. C. and Zembylas, M. (2006) 'Did the Cypriot students really cheat on TIMSS?' *Research in Comparative and International Education, Research in Comparative and International Education,* Vol. 1: 120-125.

TIMSS and PIRLS International Study Center (2016) *About TIMSS 2015*. Available at http://timss2015.org/timss-2015/about-timss-2015/.

Wellington, J. and Osborne, J. (2001) *Language and Literacy in Science Education*. Buckingham, UK: Open University Press.

Woessmann, L. (2003) 'Central Exit Exams and Student Achievement: International Evidence'. In P. E. Peterson, M. R. West (eds), *No Child Left Behind? The Politics and Practice of School Accountability*. Washington, D.C.: Brookings Institution Press.

Woessmann, L. (2006) 'Growth, Human Capital and the Quality of Schools: Lessons from International Empirical Research', *Strategies for Employment and Growth in Austria*, Vol. 10: 74-98.

Word Bank Report (2014) *Analysis of the Function and Structure of the Ministry of Education and Culture of the Republic of Cyprus*. The World Bank.