A comparative study of Flemish and Chinese children’s mastery of basic arithmetic operations

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Abstract

The present paper aims to investigate differences between Flemish and Chinese children from grade 3 till 6 mastering the four basic arithmetic operations (addition, subtraction, multiplication and division). Firstly, the result showed that Chinese students outperformed Flemish students in each of the grades due to the high demanding curriculum in China. Difference in addition, subtraction and division skills between Chinese and Flemish students decreased with increasing grade. Secondly, the four arithmetic skills had different mastery levels for Chinese and Flemish students. Multiplication was relatively easier for Chinese students compared to their Flemish peers. Thirdly, the low achievers experienced comparable learning difficulties in both countries, while higher achievers reached highest mastery level at early schooling.

Key words basic arithmetic skills; fact retrieval, mathematics; Flanders; China
Introduction

For over more than 100 years, individual differences in numerical, arithmetical and mathematical performance have been included in educational and psychological studies (Brownell, 1928; Geary, 2006; Thorndike & Woodworth, 1901; Thorndike, 1922). About fifty years ago, the first systematic cross-national study on difference in mathematics performance was conducted to explore the role of cultural and social differences (Husen, 1967). Since then, differences in mathematics performance, due to different educational systems, have been confirmed in ongoing international assessments (TIMSS, PISA). Moreover, a number of worldwide comparative studies provided important information on the role of the educational system that is adopted in specific cultures (Dowker, Bala, & Liloyd, 2008). Recently, an increasing number of studies focus on both psychological and sociological explanations for differences in mathematical skills across countries (Imbo & LeFevre, 2009, in press; Zhou et al., 2009). Since both Flemish and Chinese students reflect high performance levels in the international mathematics performance indicator studies such as PISA (Prais, 2003), and this irrespective of differences in their curriculum and/or instructional approach, it is interesting to analyse differences in mathematics skills between these two countries. But, as will be explained below, the present study goes beyond a general comparison of mathematical performance.

Previous studies mainly focused on two mathematical domains: the mastery of numerical facility skills and mathematical reasoning (Chein, 1939; Dowker, 2005; Thurstone & Thurstone, 1941). In the present study the focus is on the mastery of fact retrieval skills, as these skills are a prerequisite to solve everyday problems. Moreover, numerical facility or fact retrieval skills are the basis skills for dealing with a variety of arithmetical problem-solving tasks. Children have to add, subtract, multiplicate and solve divisions accurately and as fast as possible. The present study aims to explore whether the development of these basic arithmetic operations (additions, subtractions, multiplications, divisions) differ in Chinese and Flemish primary school children with different levels of ability. Presenting the development of basic arithmetic operations skills as the basics of mathematics, the current study addresses two research questions:

(a) Is there an impact of cultural background (e.g., language, curriculum, teaching practices, etc.) on students’ development of basic arithmetic operations skills? And if so, are these differences also apparent in low- or high-achieving children in all? If the curriculum plays an important role, the differences between Chinese and Flemish are supposed to decrease with increasing grade since the curriculum objective is the same for both countries at the end of grade six. However, if language of culture plays an important role, no such age-related decrease in the differences between Chinese and Flemish children will be found.

(b) Are the differences between the mastery of the arithmetic operations the same in both countries, in all school grades and for students with low- or high mathematical abilities? For example, is addition easier than division in both cultural settings?

Differences in the development of basic arithmetic skills

Basic arithmetic skills are defined as the combination of arithmetical computation and a conceptual understanding of number relationships and arithmetical concepts (Ary, 2006;
In the next section, we focus on the development and mastery of basic arithmetic skills in Flemish and Chinese primary school children.

**Cultural differences between Flanders and China**

Cross-national comparative studies of mathematics performance consistently show how East-Asian children outperform Western children on numerical and arithmetical skills; more specifically on addition and subtraction tasks (De Corte, Greer, & Verschaffel, 1996; Geary, Bow-Thomas, Fan, & Siegler, 1993; Robitaille & Travers, 1992). These differences in performance have been attributed to a number of cultural variables and processes, such as language (Colome, Laka, & Sebastian-Galles, 2010; Whorf, 1956) and the educational system (Campbell & Xue, 2001; Greay, Bow-Thomas, Fan, & Siegler, 1996). However previous studies revealed that cultural differences are not only observed in school-age children but also in adults and preschoolers, -suggesting that schooling is only one of the factors explaining differences (Imbo & LeFevre, 2009, in press; Siegler & Mu, 2008), and additional explanations could be related to e.g., linguistic differences (Colome, Laka, & Sebastian-Galles, 2010).

Linguistic differences can play a role in a number of ways. First, it is argued that the transparency of the counting system in a particular language, might influence the working memory span (Baddeley, 2000; Raghubar, Barnes, & Hecht, 2010), and as such influence performance in mathematics. In this light, several studies revealed the advantage of about two items in the digit span for Chinese children, helping to explain their higher performances on basic arithmetic tasks (Geary, Bow-Thomas, Liu, & Siegler, 1996; Stigler, Lee, & Stevenson, 1986). Second, previous studies explored the role of specific mathematical language in mathematics performance. According to Seron and Fayol (1994), the way numbers are represented in a language influences the processing of numbers and as such affects students’ mathematical performance. The role of this specific mathematical language is reflected in the triple code model of Dehaene and his colleagues (Dehaene, 1992; Dehaene & Cohen, 1995). According to this model, there are three internal representations of numbers: an analogue magnitude system, a visual Arabic sketchpad, and a verbal system. Especially this verbal code would be affected by the language used in a cultural setting.

Next to the exploration of language as a determinant of differences in mathematical performance, also school related variables could play a role. Differences in the curriculum structure (sequencing of curriculum topics), textbook design and didactical strategies adopted by teachers are expected to affect the development and mastery of numerical facility skills (Geary, Bow-Thomas, Fan, & Siegler, 1996; Xin, 2007). If there are clear differences in the exposure to basic arithmetic skills during primary school, it can be expected that students will evolve in different ways (speed, timing) from an explicit procedural strategies usage during the early years to memory retrieval strategies in later years (Koshmider & Ashcraft, 1991; Siegler, 1988). Since school related variables interact with language, a preliminary analysis was carried out to analyze the curriculum program in Flanders and China in view of the curriculum content, the didactical approaches being adopted and the time weekly spent for mathematics. The results of this preliminary analysis are summarized in Appendix 1a, 1b and 1c. There were no big school related differences between Flanders and China. Only one key difference was present, namely the curriculum in China is clearly more demanding during the initial school grades compared to the curriculum program in Flanders. It is therefore argued that next to expected differences during
early years caused by language domain, differences in fact retrieval skills might mainly to be explained by differences through the country differences in education, etc..

**Differences between low-, average- and high- performers in both countries**

While the majority of comparative studies solely focused on the development of basic arithmetic skills in “normal” achieving students (Wang & Lin, 2009), little comparative research has been set up that centres on students with varying mathematics skills (Desoete, Stock, Schepens, Baeyens, & Roeyers, 2009; Geary & Hoard, 2005). Therefore, the present study will also focus on the differences between low, average and high performing children in both countries. Since previous studies indicate that students with mathematical learning difficulties show deficits in particular numerical skills (i.e., arithmetic procedural skills, number fact retrieval, place value concept, and number sense) and two domain-general processing skills (i.e., working memory and processing speed) (Chan & Ho, 2010), it is expected that students with poor mathematics skills will experience more difficulties in executing basic number tasks that require automatization of number retrieval facts from long-term memory than students with profound mathematics skills (Desoete et al., 2009; Geary & Hoard, 2005). Thus, the basic arithmetics skills can be called number retrieval facts skills. In addition, it will be interesting how this interacts with cultural variables.

**Patterns in the mastery and development of the four basic arithmetic operations skills**

Children learn to solve four basic operations: additions, subtractions, multiplications, and divisions. Several studies have indicated that these tasks differ in terms of difficulty level (Campbell, 1999; Siegler, 1996), Fayol (1990) and Siegler (1996) stated that addition skills are mostly the result of informal learning and develop along with children’s acquisition of counting skills at the early beginning of their school career, whereas multiplication skills are the results of formal learning. In addition Campbell (1997; 1999), revealed a mediation effect between addition and subtraction on the one hand and multiplication and division on the other hand. Campbell (1997; 1999) underlining the fact that knowledge of one operation mediates the performance on other operations. These research findings can be linked to the sequencing in the attention paid to particular operations in the curriculum program. Addition is treated prior to subtraction, multiplication, divisions.

Psychological studies indicate that multiplication and addition tasks or more often solved by fact retrieval than in subtraction and division tasks, (Campbell & Xue, 2001). In addition, Thevenot, Castel, Fanget and Fayol (2010), showed that only high achieving students use retrieval strategies in solving mental subtraction skills. Moreover, studies from a neuropsychological perspective revealed that, while addition tasks relied on visuo-spatial processing, multiplication tasks mainly build on verbal processing (Imbo & LeFevre, 2010; Zhou, 2007). To conclude, studies provided evidence for important differences between the developments of four distinct basic arithmetic skills in young children.

In the context of the present comparative study, an analysis of the mastery and development of the four fact retrieval skills will be conducted. Next to general differences in mastery of the four operations, a more fine-grained comparison – in relation to differences between countries, grades and mathematical ability level – might be a step forward compared to earlier research.
When differences are found, they can influence future decisions as to the design of the curriculum and the teaching and learning environment. For example, if multiplication is easier than addition for Chinese students but not for Flemish students, then we can put the multiplication content earlier in the textbook in China than in Flanders.

Methodology

Sample

A total of 7247 Chinese students and 913 Flemish students, enrolled in grade 3 to grade 6 of primary education, were involved in this study. Flemish students were enrolled in twenty-one schools. The 7247 Chinese students were selected from twenty schools in five different provinces and cities. After test administration (see below), all students were asked to provide information on gender and grade. Descriptive statistics for grade and gender are presented in Table 1.

<Insert Table 1 about here>

Procedure

All ability measures were obtained in the setting of the classroom of the pupils and following a standard protocol. All participants were first tested on their basic arithmetic skills followed by an assessment of their mathematical abilities. The test administration lasted about 5 minutes for the basic arithmetic operations test and 40-50 minutes for the mathematics abilities test.

Basic arithmetic skills

The standardized test of basic arithmetic operations tasks (Tempo Test Rekenen, TTR; De Vos, 1992) was administered to both Flemish and Chinese primary school children. The TTR is a ‘timed’ test consisting of 200 arithmetic number fact problems. Children have to solve as many additions (e.g., 5 + 2 = …), subtractions (e.g., 6 - 5 = …), divisions (e.g., 2 x 8 = …), multiplications (e.g., 16 : 4 = …) and mixed exercises in five minutes. In this paper, we only included the first four columns, not the mixed operation column (See Appendix 1a).

Determining mathematical achievement levels

All students in were also screened on general mathematical achievement aligned with the local curriculum.

In Flanders, the students were assessed with the Kortrijk Arithmetic Test–Revised (Kortrijkse Rekentest Revision, KRT-R; Baudonck et al., 2006). The Kortrijk arithmetic Test Revision (KRT-R; Baudonck et al., 2006) is an untimed standardized test on procedural calculations. KRT-R requires that children solve simple calculations in a number-problem format (e.g., 39 + 60 = ) or word-problem format (e.g., 6 more than 48 is …). The psychometric value of the test has been demonstrated on a sample of 3,246 children.

In China, children were tested with a test covering the new curriculum syllabus from 2001. The test had a good psychometric value with alpha values ranging between .95 and .93 (Authors, 2011).
Both tests (the KRT-R and the Chinese test) tested were based on the same construct measuring number reading skills, mathematical lexicon, knowledge, procedural knowledge, linguistic skills, mental representation, contextual skills, selecting relevant information, number sense, and memory in young children.

These tests were used to distinguish between three groups of children: low performing children (25%), an average performing group (50%), and a high performing group of students (25%).

**Content analysis**

An in-depth analysis of the curriculum in China en Flanders took place (See Appendix 1a). In addition, a commonly used Chinese mathematics textbook series (SHUXUE) was compared to a frequently used textbook series in Flanders (KOMPAS). Both textbook series are geared to the mathematics standards and the mathematics curriculum that currently determine mathematics instruction in Flemish and Chinese primary education.

**Data Analysis**

In a first step, the correlation between the fact retrieval skills on additions, subtractions, multiplications and divisions was computed. Next, a 4(Grade) x 2 (country) x 3 (achievement levels) MANOVA was conducted to evaluate differences between the four basic arithmetics skills (additions, subtractions, multiplications, divisions) of Flemish and Chinese students, considering the different levels of mathematical achievement. In a second step, a paired-samples t-test was computed to compare the differences between the four arithmetic facts in each separated subsample. Then, a 4(Grade) x 2 (country) x 3 (achievement levels) MANOVA was conducted on the six differences between each two numerical facilities. These six differences include difference between scores of addition and subtraction, addition and multiplication, addition of division, subtraction and multiplication, subtraction and division, multiplication and division. Next, if the MANOVAs performed in step 1 and 2 were significant; ANOVAs were carried out, in order to study the nature of the differences. Simple mean values were contrasted by means of the HSD procedure. A significance value of p < .01 level was stated in view of all analyses.

**Results**

**Descriptive results**

The correlation between the four arithmetic operations were computed for the two countries. Table 2 shows how mastery of all four skills is strongly correlated in both countries (see Table 2).

<Insert Table 2 about here>

**Differences between countries, grade and mathematics achievement level and interaction effects on four particular fact retrieval skills**
In this section, the four basic arithmetic skills were studied together. There were no significant gender differences (entire sample, or within countries) ¹.

To look for differences between countries, grade and achievement level, multivariate analysis of variance (MANOVA) was carried with the four basic arithmetic operations as dependent variables. Significant differences between countries, grades and mathematics achievement level were found. There were significant multivariate differences between countries \((F(4,8144)=593.14, \ p<.01, \ \eta^2 = .23)\), grades \((F(12,21539.353)=84.64, \ p<.01, \ \eta^2 = .04)\) and mathematics achievement level \((F(8,16282)=96.65, \ p<.01, \ \eta^2 = .05)\). Also, interaction effects for country x grade \((F(12,24539.353)=10.17, \ p<.01, \ \eta^2 = .01)\), and grade x mathematics achievement level \((F(24,28401.77)=10.16, \ p<.01, \ \eta^2 = .01)\) were present. The effect size for interaction country x grade \((\eta^2 = .01)\) and grade x ability \((\eta^2 = .01)\) was small, while the effect size for country \((\eta^2 = .23)\) was of a medium size (Green, Salkind, & Akey, 2000).

To study differences between countries, grade and mathematics achievement level for each of skill separately, univariate analyses (ANOVA) for additions, subtractions, multiplications and divisions were computed. As showed in Table 3, the score for the four arithmetic operations was higher for Chinese students than Flemish students. Also, the score for the four arithmetic operations was higher for the older (higher grade) students than for the younger (lower grade) students. Higher achievers did better than lower achievers on fact retrieval skills. All of these p values were smaller than .01.

<Insert Table 3 about here>

Do students in both countries achieve the same in fact retrieval skills? The interaction of country x grade was studied. Descriptions are represented in Figure 1. Significant interaction effects were found for additions \((F(3,8144) = 7.06, \ p<.001, \ \eta^2 = .003)\) and divisions \((F(3,8144) = 9.13, \ p<.001, \ \eta^2 = .003)\) There was no significant interaction effect for subtraction \((F(3,8144) = 2.68, \ p=.045, \ \eta^2 = .001)\) or multiplication \((F(3,8144) = 2.53, \ p=.055, \ \eta^2 = .001)\). When the file was split by country the dataset revealed an unstable improvement for the different grades on additions and divisions for Chinese students while the improvement was stable for the Flemish sample (See Figure 1). As Figure 1 revealed, the differences between China-Flanders students on the addition and subtraction score decreased with age (or grade; all of the p<.001), except for multiplication and division. For the Chinese students in Grade 5, the score on subtractions \((M=30.28)\) and multiplications \((M=34.29)\) did not differ significantly from their score on subtraction \((M=31.29, \ p=.162)\) or multiplication \((M=34.42, \ p=.697)\) in Grade 6. For the results on multiplications and divisions we refer to Figure 1.

<Insert Figure 1 about here>

¹ A MANOVA analysis confirmed that no main effect of gender or any interaction effects were found (Country X Gender, Math X Gender, Grade X Gender for the addition, subtraction, multiplication, division and mixed calculation). Also, the MANOVA reveals that there were no interaction effects of mathematics ability and country or grade for the four arithmetic skills and six pair of the difference between each two of the four operations.

² Since four tests were done for the univariate here and we required an experiment-wise alpha rate of .01, so we will divide it by four to get an acceptable confidence level for each of the four tests, so we will set the alpha level to \(p < .003\). With a more lenient criterion of .05 (and a greater probability of Type I error), two other univariate tests would have been significant. In the following, the same criterion would be adapted.
To look for differences between low, average and good mathematical achievers, the interaction of grade x achievement level was studied with ANOVA’s. There was a significant interaction effect for addition ($F_{(6,8144)} = 18.61$, $p<.001$, $\eta^2 = .014$), subtraction ($F_{(6,8144)} = 12.09$, $p<.001$, $\eta^2 = .009$), multiplication ($F_{(6,8144)} = 14.93$, $p<.001$, $\eta^2 = .011$) and division ($F_{(6,8144)} = 11.09$, $p<.001$, $\eta^2 = .008$). To examine the interaction, the file was split by achievement levels and a MANOVA was run for grade. The difference between grades for average achiever and lower achiever became smaller for subtraction and multiplication. For the lower achiever and average achiever in Grade 5, the score on subtraction and multiplication was not significantly different from corresponding peers in Grade 6. For the higher achiever in Grade 3, the score on addition and subtraction were not significantly different from higher achiever in Grade 4.

**Differences between countries, grade, achievement level and interaction effects on the basic arithmetic skills**

**Do four basic arithmetic skills have different mastery level?**

In this second section, we explored the potential differences between the four arithmetic skills. In the previous section, as Table 3 revealed, Flemish and Chinese students differed on the difficulty of the four arithmetic skills. Flemish students, solved more addition (M=21.16) in one minute compared to the number of subtractions (M=19.86), multiplications (M=18.85) and divisions (M=15.55). They solved more subtractions than multiplications. This was not the case for the Chinese students: additions (M=32.36), multiplications (M=31.05), subtractions (M=28.12) and divisions (M=24.54). In order to check for the difficult mastery levels, a paired-samples t-test was conducted to compare - pairwise – the difference for each two of the four basic arithmetic skills for Flemish and Chinese students and in each grade (See Table 4). All of the paired sample t-tests were significant at the .001 level in each of the separated subsample. In general, both Chinese and Flemish students achieved significantly higher results for additions compared to the other fact retrieval tasks Students also attained significantly higher results for subtraction tasks compared to the number of divisions they solved in one minute. Moreover, students performed significantly better on multiplication tasks than on a division task. These results are in line with the sequencing order in which topics are introduced in the curricula, except for the multiplication results of the Chinese students. As Table 1a in Appendix showed, addition and subtraction were taught to Flemish and Chinese student from Grade 1. And then it was followed by the multiplication and divisions in Grade 2 for both countries.

<Insert Table 4 about here>

**Do additions, subtraction, multiplications and divisions have the same difficulties level in both countries?**

In order to explore whether the four basic arithmetic skills have the same difficulties level for both countries, a multivariate analysis of variance (MANOVA) was conducted performed with country, grade and mathematics achievement level as independent variables and the differences between six pairs of basic arithmetic skills as dependent variables. Results revealed that an main effect for country ($F_{(3,8142)}=148.67$, $p<.01$, $\eta^2 = .05$), grade ($F_{(9,19815,639)}=31.32$, $p<.01$, $\eta^2 = .01$) and mathematics achievement ($F_{(6,16284)}=49.63$, $p<.01$, $\eta^2 = .02$), and an interaction between country x
grade \((F(9,19815.659)=12.70, p<.01, \eta^2 =.005)\) and between grade x mathematics ability \((F(18, 23029.54)=6.69, p<.01, \eta^2 =.005)\). Given the significance of the overall test, the univariate main effects and interaction effect were examined step by step.

Do the addition, subtraction, multiplication and division have the same difficult level for the Chinese students and Flemish students? Significant univariate main effects for country were obtained for five pairs except for pair of subtractions and divisions \((F(1,8144)=6.60, p=.010, \eta^2 =.001)\). The difference between subtraction and division was the same for Flemish students \((M=4.31)\) and Chinese students \((M=3.58)\) \((p=.022)\) (See Figure 2). The others differences were not the same for these two countries (See Figure 2). Chinese students achieve 2.90 points higher in multiplication versus subtraction, while Flemish students score 1.01 points higher on subtraction versus multiplication (See Figure 2). Multiplication tasks seem to have a different position in the context of both curricula.

<Insert Figure 2 about here>

Do the addition, subtraction, multiplication and division have the same difficult level for all grades? Significant univariate main effects were obtained for three pairs of differences between addition and division \((F(3,8144)=43.24, p<.01, \eta^2 =.016)\), subtraction and division \((F(3,8144)=75.05, p<.01, \eta^2 =.027)\), and multiplication and division \((F(3,8144)=69.87, p<.01, \eta^2 =.025)\). These Table 4, for all the results. Students became more and more familiar with division because of the curricular (See Appendix 1a).

Do the addition, subtraction, multiplication and division have the same difficult level for different achievement levels students? Significant univariate main effects were obtained for most of six pairs except for the pair of addition and multiplication \((F(2,8144)=.37, p=.373, \eta^2 =.000)\), subtraction and division \((F(2,8144)=3.140, p=.04, \eta^2 =.001)\). There were no significant differences between the lower achiever, average achiever and higher achiever for the score on the pairs of addition and multiplication, subtraction and division.

Do the addition, subtraction, multiplication and division has the same difficult level for both countries (See Table 4)? The interaction of country and grade was entered into the univariate analyses. The significant interactions were found five pairs of addition-multiplication \((F(3,8144) = 10.89, p<.001, \eta^2 =0.004)\), addition-division \((F(3,8144) =27.55, p<.001, \eta^2 =0.004)\), subtraction-multiplication \((F(3,8144) =6.64, p<.001, \eta^2 =0.002)\), subtraction-division \((F(3,8144) =30.32, p<.001, \eta^2 =0.011)\), multiplication-division \((F(3,8144) =15.25, p<.001, \eta^2 =0.006)\). Then, the file was split by country to examine the interaction. Firstly, the results showed that the score for pair of addition-division, subtraction-division, and multiplication-division decreased with the growing of the grade for Chinese students (all of the p value is smaller than .001) while there is not the case for the Flemish students. For the Flemish students in Grade 3, scores on these pairs on division and other three operations were significantly higher than score of students in Grade 4, 5 and 6 (all of these p values were smaller than .001). But there were not significantly different for Flemish students between Grade 4, 5 and 6 (all of these p values were bigger than .05). Secondly, the absolute score for pair of subtraction-multiplication decreased with grade for Chinese students (all of these p values were smaller than .001) while there was no difference between grades for the Flemish students (all of these p values were bigger than .05). Thirdly, for the score of addition-multiplication, Flemish students in Grade 3 and Grade 4 achieved higher than students in Grade 5 and 6 (all of these p values were smaller than .01) while Chinese students in Grade 3, and 5 achieved higher than students in Grade 4 and 6 (all of these p values were smaller than .01).
Do the addition, subtraction, multiplication and division have the same difficult level for different achievement level students considering their curriculum in different grade? For another interaction effect of grade and achievement level, significant univariate main effects were obtained for five pairs on addition-multiplication ($F_{(6,8144)} = 4.17, p<.001, \eta^2 =.003$), addition-division ($F_{(6,8144)} = 11.05, p<.001, \eta^2 =.008$), subtraction-multiplication ($F_{(6,8144)} = 6.35, p<.001, \eta^2 =.005$), subtraction-division ($F_{(6,8144)} = 13.72, p<.001, \eta^2 =.010$), multiplication-division ($F_{(6,8144)} = 6.38, p<.001, \eta^2 =.005$). If the file was split by grade to examine the interaction effect, different pattern would be found between lower achiever, average achiever and higher achiever at different grade. There were two results should be focused. Firstly, in grade 6, for the pair of addition and division, subtraction and multiplication, subtraction and division, multiplication and division, there were significantly difference between lower achiever, average achiever and higher achiever (all of these p value were smaller than .01) while there was not the same for the lower grade levels. Secondly, for the pair of addition and multiplication, there were not significant difference for the lower achiever, average achiever and higher achiever in grade 3, 4 and 6 (all of these p value were bigger than .05). The results revealed difference on the four pairs between the low, average and high achievers increasing with the grade except for addition and multiplication and addition and subtraction.

Discussion

The present comparative study of Flemish and Chinese children’s basic arithmetic skills revealed cross-cultural between children.

Difference in four basic arithmetic skills

Chinese students outperformed Flemish students in the four basic arithmetic skills

The results of the present study indicated that Chinese primary school students outperformed Flemish students on all numerical facility skills. This finding was in line with previous research that indicates that East Asian students outperform their Western peers (Imbo & LeFevre, 2009, in press). The pedagogical content in Flanders and China were mainly comparable (See Appendix 1b and c). As we can see in Appendix 1b, teachers in both countries made use of the place-value concept to teach addition and subtraction and they valued the number line to help the children understand the meaning of the place value. For example, the addition was taught by separating the number into different pairs of small number. Eight was the result of four adds four, or the result of two adds six, etc.(See Appendix 1b). In both countries, the students had to understand the big numbers can be combined by small numbers. And for the multiplication, the students had to understand the meaning of each multiplication, $5 \times 2$ is five times two. Also, the multiplication table had to be recited in both countries. Moreover, the teaching time for fact retrieval in Flemish and Chinese students was the comparable. There were among four or five lessons per week. But, the the teaching is much more demanding in China for the first two grades as can be concluded form Appendix 1a. For example, Chinese students in grade 1 make exercises up to 100, whereas Flemish students only solve exercises with numbers smaller than 20 in Grade 1. Also, in Grade 2 there are differences, with Flemish students making exercises with numbers up till 100 and Chinese students calculating up till 10000. This continues for the other grades, making the
syllabus for both countries not comparable and Chinese children getting a more demanding education of fact retrieval and other mathematic skills.

The differences between additions, subtractions and divisions between Chinese and Flemish students decreased with grades while multiplications had a somehow different position

The results of the current study indicated that the curriculum content of each grade partly had an impact on the student performance. The analyses showed a significant effect of grade on children’s performance in addition, subtraction and division. There was no doubt that the grade played an important role in the development of the basic arithmetic operations. How about the interaction between grade and country?

For addition, subtraction and division score, these differences between Chinese and Flemish students decreased in higher grades. The differences in performance between Chinese and Flemish students can partly be explained by the differences in curriculum content. (See Appendix 1a).

An interesting result can be found with regard to multiplication tasks: no significant interaction effect of country x grade is observed. The result indicates that the difference on multiplication between Flemish and Chinese students does not decrease when children get older although this was the case for additions, subtractions and divisions in fact retrieval tasks (See Figure 1). Though Zhou et al., (2006) state that two types of strategies can be used to complete simple arithmetical tasks: procedural strategies and rote verbal memory strategies, the current findings suggest that both Chinese and Flemish students rather apply rote memory strategies to memorize multiplication facts. This is confirmed by the curriculum analysis (appendix 1b) that show how in both countries, rote verbal strategies are applied to teach the multiplication table.

Lower achievers remain below-average performers, while higher achievers master the arithmetic facts at a younger age

In the current study, we distinguished between low, average and high performing students. As expected, a main effect of achievement level was found. The higher achievers outperformed the lower achievers on fact retrieval tasks. However, the main question was whether students with different ability levels, performed differently when getting older.

For the lower achievers, the subtraction and multiplication scores did not increase from grade 5 to grade 6. For the group of high achievers, the students in Grade 3 already did equally good on additions and subtractions than the children in Grade 4 (see Appendix 1a).

Previous studies showed that the mental representations to solve the elementary number combinations are different for high and low achieving students (Desoete et al., 2009; Pitta & Gray, 1997). Low achievers’ mental representations were strongly associated with procedural aspects of numerical processing while the high achievers’ mental representations rather focus on abstractions (Pitta & Gray, 1997).

The basic arithmetic skills have different difficulties position for children in China and Flanders
Students performed best on addition tasks, followed by subtractions, multiplications and division tasks in Flanders. In China additions were also the easiest, followed by multiplications, subtractions and divisions this order in masterly levels obviously reflects the curricular arrangement in general (see appendix 1a). In both countries children are first taught addition skills, to continue with subtraction and multiplication, followed by division skills. However it is unclear why Chinese students have fewer problems with multiplications than with subtractions.

Perhaps this difference can be explained by linguistic differences between both countries. Previous studies stressed the importance of the linguistic transparency in learning the counting system (Dowker, Bala, & Lloyd, 2008). In addition, the Chinese language for reading numbers is very transparent and consistent. How you pronounce a number word, is how you write the Arabic number. For example, in Chinese, the number 72 is read as qi shi er (seven ten two); in which qi represents the number 7, er refers to the number two and shi refers to the place value ten. In Dutch, on the other hand, the reading of numbers is inconsistent with the Arabic number representation: 72 is read as tweeënzeventig (two and seventy). This might explain why Chinese children perform better in multiplication tasks than in subtraction tasks, whereas the opposite order was found in Flemish children. Thanks to a more straightforward linguistic system, Chinese children seem to apply retrieval strategies quicker than Flemish students (Imbo & Lefevre, 2009). For example, it is easier for the Chinese students to remember “nine multiplied by nine is eighty-one” (jiu jiu ba shi yi) while it is a little difficult for Flemish students to remember the result of nine multiplied by nine is one-and-eighty (“eenentachtigt”),

In Flanders children improve longer, whereas students in China reach higher difficulty levels on basic arithmetic skills at younger age.

An interaction effect of grade X country was found for the comparison of addition with multiplication, addition with division, subtraction with multiplication, subtraction with division, and multiplication with division.

For Chinese students, the three differences with division (addition-division, subtraction-division and multiplication-division) decreased with increasing grade. However, for Flemish students, the differences between the other operations and divisions did not change with grade. This implies that the improvement in addition, subtraction, multiplication and division were the same with increasing grade for Flemish students (See Figure 1). But, for the Chinese students, the improvement of division was larger (see Appendix 1a). This might be explained by the fact that Chinese students had been required to reach the higher mastery level for addition, subtraction and multiplication at the lower grade, such as grade 1, 2, 3.

Differences between additions and multiplications and between additions and subtractions between higher achievers, average achievers and lower achievers

It was found that the interaction effect of grade x achievement level only was significant in pairs of addition-multiplication, addition-division, subtraction-multiplication, subtraction-division, and multiplication-division. And, for the pair of addition-multiplication, only in Grade 5, the difference between lower, average and higher achievers existed. Then, it implied that the difference between addition-multiplication and addition-subtraction were relatively stable than
others. There is little background literature to understand our data. Additional research is needed to replicate the data and to look for reasons of this data.

Conclusions, Limitations and future study

The present study reflects a number of limitations that should be considered in future research. First, future research is needed going beyond the “product” level of mathematics learning and mapping the differences on actual processes and strategies being adopted by students in the different cultural settings.

Second, the “cultural” dimension was approached in a rather general way. Next to a focus on language differences, only a number of curriculum related differences were considered (curriculum content, basic didactical approaches, timing, ...). Other factors should be considered in an explicit way to study cultural differences; e.g., the actual teaching approach, homework, shadow education, the impact of parents, etc.

Thirdly, for the higher achiever, Flemish students obtained better results in four arithmetic skills during subsequent school grades. This can be explained by the Chinese students who already attain in the early grades a ceiling level that hardly changes during subsequent grades.

Fourthly, both Flanders and China are highly ranked in the PISA list. It could be interesting to involve other countries in the cross-cultural studies that reflect critical performance differences.

Despite the limitations mentioned above, the present study also introduces a number of new directions. Firstly, the present study re-proved that Chinese students outperformed Flemish students in four basic arithmetic (fact retrieval) skills. But with the increasing of schooling, the difference between Chinese students and Flemish students decreased for additions, subtractions and divisions. This might be explained by differences in curriculum. Secondly, although the curriculum were arranged by order of addition, subtraction, multiplication and division, our dataset revealed that multiplications have a different difficult level for Flemish and Chinese students. This was not caused by the curriculum and pedagogical approaches but it might be explained by the linguistic differences. This might indicate that in China, the multiplication can even be taught at a younger age.

Thirdly, we found striking differences between poor, average and good mathematic performers, with poor performers not catching up their retardation. Additional research is needed with a longitudinal design to study the difference in developmental patterns between these children.
References


Authors (2011)
### Table 1
Sample characteristics

<table>
<thead>
<tr>
<th>Country</th>
<th>Gender</th>
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<th>Grade 4</th>
<th>Grade 5</th>
<th>Grade 6</th>
<th>Total</th>
</tr>
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<tr>
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<td>100</td>
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<tr>
<td></td>
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<td>155</td>
<td>73</td>
<td>103</td>
<td>481</td>
</tr>
<tr>
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<td>872</td>
<td>852</td>
<td>847</td>
<td>917</td>
<td>3488</td>
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<tr>
<td></td>
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<td>933</td>
<td>979</td>
<td>904</td>
<td>943</td>
<td>3759</td>
</tr>
<tr>
<td>Total</td>
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<td>2074</td>
<td>2132</td>
<td>1924</td>
<td>2030</td>
<td>8160</td>
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### Table 2
Correlations between the fact retrieval skills

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<th>Addition</th>
<th>Subtraction</th>
<th>Multiplication</th>
<th>Division</th>
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<td>.70**</td>
<td>.66**</td>
</tr>
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<td>Subtraction</td>
<td>.75**</td>
<td>-</td>
<td>.72**</td>
<td>.72**</td>
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<td>Multiplication</td>
<td>.61**</td>
<td>.78**</td>
<td>-</td>
<td>.82**</td>
</tr>
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<td>Division</td>
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<td>.76**</td>
<td>.79**</td>
<td>-</td>
</tr>
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</table>

Note: Correlations for Flemish students are presented above the diagonal, and correlations for Chinese student are presented below the diagonal.

*\(p<.05\) ** \(p<.01\)
Table 3
Comparision of the fact retrieval skills in different groups

<table>
<thead>
<tr>
<th>Source</th>
<th>Subgroup</th>
<th>Additions M (SD)</th>
<th>Subtractions M (SD)</th>
<th>Multiplications M (SD)</th>
<th>Divisions M (SD)</th>
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</thead>
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<td></td>
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</table>

Note:
Add: Addition; Sub: subtraction; Mul: multiplication; Div: division.