International Electronic Journal of

# Mathematics Education

Volume 3, Number 1, February 2008 www.iejme.com

# REVISITING THE INFLUENCE OF NUMERICAL LANGUAGE CHARACTERISTICS ON MATHEMATICS ACHIEVEMENT: COMPARISON AMONG CHINA, ROMANIA, AND U.S.

**Jian Wang**

**Emily Lin**

**Madalina Tanase**

**Midena Sas**

**ABSTRACT.** Eastern Asian students repeatedly outperform U.S. students in mathematics. Some suggest that number-naming languages consistent with the base-10 number system found in many Eastern Asian countries presumably contribute to their students' better understanding of the base-10 system and consequential performance. Such language features do not exist in English or other Western languages. The current study tests this assumption by comparing base-10 knowledge of students in kindergarten and first-grade from China, Romania, and U.S. who have developed number-naming language abilities but received relatively little formal school instruction. It is expected that since Chinese number-naming is linguistically more transparent and consistent with the base-10 system, Chinese students should outperform both their Romanian and U.S. peers. Romanians should show intermediate performance between Chinese and U.S. students since Romanian language is somewhat transparent and consistent with a base-10 system while English number-naming language is least consistent. However, the analysis of this study revealed that although Chinese children outperformed both Romanian and U.S. counterparts in accomplishing base-10 tasks, there were no significant differences between Romanian and U.S. children. This finding suggests that the extent to which number-naming language is linguistically transparent and consistent with the base-10 system may not necessarily align with the level of children's understanding of the base-10 system and relevant mathematics performances.

**KEYWORDS.** Asian, American, Romanian, Language, Cognitive Representation.

## INTRODUCTION

As shown in many international comparisons, Eastern Asian students are typically the top international mathematics performers across various grade levels (Mullis et al., 1997; Mullis et



ISSN: 1306-3030

al., 2004; Mullis et al., 2000; Programme for International Student Assessment, 2004; Stigler et al., 1990). However, how they attain such performances is less well understood and this has resulted in a multitude of interpretations and lines of research (Wang & Lin, 2005).

Much of the mainstream research points to differences in schooling factors between Eastern Asian countries and U.S. as an interpretation. This line of research suggests that in comparison with Eastern Asian countries, U.S. school mathematics curriculum materials are less focused and more repetitive when examining content coverage, instructional requirements, and structures (Mayer et al., 1995; Schmidt et al., 1999; Schmidt et al., 1996b). U.S. curriculum policy is also less authoritative, specific, and consistent (Cohen & Spillane, 1992; Eckstein, 1993; Wang, 2001). In addition, teachers in Eastern Asian countries are able to develop a deeper understanding about mathematics and its representations (Ma, 1999) and provide clearer explanations, make more efficient use of their class time, develop smoother pedagogical flow, and engage more students in inquiry using whole class instruction (Perry, 2000; Schmidt, et al., 1996a; Stigler & Hiebert, 1999; Stigler et al., 1987). Furthermore, Eastern Asian teachers are able to plan, observe, and reflect on each other's instruction to improve their teaching practices (Lewis, 2000; Stigler & Hiebert, 1999; Wang & Paine, 2003). These findings have exerted important influences on U.S. mathematics education reform featuring the establishment of mathematics curriculum standards and engagement of teachers to examine and reflect on one another's instruction (Romberg, 1997; 1999).

Other researchers focus on non-schooling factors to explain the performance differences between Eastern Asia and U.S. (Wang & Lin, 2005) since solely focusing on schooling factors cannot explain why Asian students in the U.S., who have little or no exposure to the kinds of teaching and curriculum in Eastern Asia, are still better mathematics performers than other American racial groups (Chen & Stevenson, 1995; Kaufman et al., 1998; Sanchez et al., 2000; Stevenson et al., 1990). These non-schooling factors include student intelligence (Flynn, 1991; Lynn, 1991); self-esteem and self-efficacy (Leung, 2002; Stevenson et al., 1993; Wilkins, 2004); academic expectations and effort (Chen & Stevenson, 1995; Chiu, 1987; Tuss et al., 1995); family education values, expectations, and support (Crystal & Stevenson, 1991; Hess & Others, 1987; Huntsinger et al., 2000; Patterson et al., 2003); and language clarity, word structure, and patterns (Geary et al., 1993; Han & Ginsburg, 2001; Li & Nuttall, 2001; Miller et al, 2000; Miura et al., 1988; Rasmussen et al, 2006).

Along the line of research on language pattern influences, some scholars explain Eastern Asians' higher mathematics performance over U.S. students to be the result of Eastern Asian number-naming languages, such as Chinese, Japanese, and Korean, that are more linguistically transparent (Rasmussen et al, 2006) in number names and consistent with the base-10 structure (Bell, 1990; Fuson & Kwon, 1991; Geary, 1996; Miller & Stigler, 1987). Such base-10 knowledge is assumed to be the basis for students to learn and perform better in other relevant mathematics content areas (Ho & Cheng, 1997).

This assumption was supported by the comparisons of base-10 knowledge between pre-school and first grade students from Eastern Asian and those from U.S. and other European countries where number-naming languages are inconsistent with a base-10 system (Ho & Fuson, 1998; Miller & Stigler, 1987; Miller et al., 1995; 2000; Miura et al., 1988; Rasmussen et al., 2006). These comparisons together imply that the nature and extent of number-naming language's transparency and consistency with the base-10 system is associated with students' performance levels in base-10 knowledge and other relevant mathematics areas. However, existing studies predominantly examine students whose languages are either consistent or inconsistent with a base-10 system with little attention to languages that are partially consistent with the base-10 system, like that found in the Romanian language. That is, Chinese oral number-naming is linguistically more transparent and consistent while Romanian is somewhat consistent and English is least consistent with the base-10 system. If the transparency and base-10 consistency of the Chinese number-naming system determines mathematical performance, Romanian children would be expected to be intermediate between Chinese-speaking and English-speaking children in their understanding of base-10 system and representation of relevant mathematics concepts (Bloom, 2000; Siegler, 1998).

However, the findings from some large scale comparative studies contradicts the above expectation which showed that despite the somewhat transparent and consistent nature of the Romanian number-naming system with the base-10 system, Romanian students still performed below their U.S. peers in mathematics at various grade levels (Beaton et al., 1996; Mullis et al., 1998; Programme for International Student Assessment, 2004). Since these comparisons only measure Romanian students at upper elementary to high school levels, they are unable to delineate schooling and non-schooling factors, such as language, on their performances. This study is designed to test whether there is a relationship between students' performance in base-10 knowledge tasks and the transparency of number-naming language consistent with the base-10 system by examining Chinese, Romanian, and U.S. pre-school and early first grade students who have relatively little influence from formal schooling.

## NUMBER-NAMING LANGUAGE AND MATHEMATICS PERFORMANCE

Central to the research on the influences of number-naming language consistent with the base-10 system on student mathematics performance is the controversial Sapir-Whorf hypothesis about the relationship between language structure and thinking. It posits that the structures of a language strongly influences or even determines the way in which its native speakers perceive the world in a highly habituated manner (Sapir, 1949; Whorf, 1956). In the field of linguistics, such an assumption spawned substantial research to examine if different language structures, such as color terms, kinship terms, ethno-biological taxonomies, and obligatory morphosyntactic categories, like noun, numeral classifiers, and tense, can produce distinctive thinking (Gumperz & Levinson, 1996). The findings from this line of research challenge the extreme form of Sapir-Whorf hypothesis and propose that language and thinking are not significantly related at the grammar, individual speaker, and habitual levels (Lucy, 1996; Michael, 2002; Towse & Saxton, 1997).

The research on the influences of number-naming language (Miura et al., 1988) assume that numbers are mentally represented and stored through language and in Eastern Asian languages such as Chinese, Japanese, and Korean, numerical names are organized in a way that is congruent with the traditional base-10 numeration system. However, in other languages, the level of this transparency and consistency can be different. Such differences in linguistic transparency and consistency in different languages can be illustrated by comparing the number names for teen quantities between Chinese, English and Romanian languages.

**Table 1:** Numbers, Relevant Number Names and Numerical Meaning in Chinese, Romanian, and English Languages (Adapted from Takasugi, 2006)

| Number | Chinese | Meaning | Romanian | Meaning | English | Meaning |
|---|---|---|---|---|---|---|
| 1 | yi | 1 | unu | 1 | one | 1 |
| 2 | er | 2 | doi | 2 | two | 2 |
| 3 | san | 3 | trei | 3 | three | 3 |
| 4 | si | 4 | patru | 4 | four | 4 |
| 5 | wu | 5 | cinci | 5 | five | 5 |
| 6 | liu | 6 | sase | 6 | six | 6 |
| 7 | qi | 7 | sapte | 7 | seven | 7 |
| 8 | ba | 8 | opt | 8 | eight | 8 |
| 9 | jiu | 9 | noua | 9 | nine | 9 |
| 10 | shi | 10 | zece | 10 | ten | 10 |
| 11 | shi-yi | 10+1 | unsprezece | 1*over 10 | eleven | 11 |
| 12 | shi-er | 10+2 | doisprezece | 2 over 10 | twelve | 12 |
| 13 | shi-san | 10+3 | treisprezece | 3 over 10 | thirteen | 3* + 10* |
| 14 | shi-si | 10+4 | paisprezece | 4* over 10 | fourteen | 4 + 10* |
| 15 | shi-wu | 10+5 | cincisprezece | 5 over 10 | fifteen | 5* + 10* |
| 16 | shi-liu | 10+6 | saisprezece | 6* over 10 | sixteen | 6 + 10* |
| 17 | shi-qi | 10+7 | saptesprezece | 7 over 10 | seventeen | 7 + 10* |
| 18 | shi-ba | 10+8 | optsprezece | 8 over 10 | eighteen | 8 + 10* |
| 19 | shi-jiu | 10+9 | nouasprezece | 9 over 10 | nineteen | 9 + 10* |
| 20 | er-shi | 2 X 10 | doua-zeci | 2* X 10* | twenty | 2* X 10^ |
| 21 | er-shi-yi | 2X10+1 | douazeci-si-unu | (2*X10*) and 1 | twenty-one | 2* X 10^ + 1 |
| 22 | er-shi-er | 2X10+2 | douazeci-si-doi | (2*X10*) and 2 | twenty-two | 2* X 1^ + 2 |
| 30 | san-shi | 3 X 10 | trei-zeci | 3 X 10* | thirty | 3* X 10^ |
| 40 | si-shi | 4 X 10 | patru-zeci | 4 X 10* | forty | 4* X 10^ |
| 50 | wu-shi | 5 X 10 | cinci-zeci | 5 X 10* | fifty | 5* X 10^ |
| 60 | liu-shi | 6 X 10 | sai-zeci | 6 X 10* | sixty | 6* X 10^ |
| 70 | qi-shi | 7 X 10 | sapte-zeci | 7 X 10* | seventy | 7* X 10^ |
| 80 | ba-shi | 8 X 10 | opt-zeci | 8 X 10* | eighty | 8* X 10^ |
| 90 | jiu-shi | 9 X 10 | noua-zeci | 9 X 10* | ninety | 9* X 10^ |

* Different Form
^ Different Word

As shown in Table 1, in Chinese number-naming, the teen words are represented as ten plus some ones: 11 is simply "ten one," 12 is "ten two" and 13 is "ten three." This pattern continues into the decade numbers where 20 is "two ten," 30 is "three ten" and 45 is "four ten five." Such a number-naming language makes it relatively transparent that the number system is base-10.

Romanian number-naming words are somewhat similar to Chinese number words in terms of a base-10 system except for the following variations. First, in Romanian, the word representing 11 to 19 are reversed, with ones coming before the ten. For example, in the Romanian number naming language: 11 is “one over ten”, 12 is “two over ten”, 20 is “two times ten”, 30 is “three times ten”, and 45 is “four times ten and five.” This structure is much more consistent with base-10 system when compared with the English language. Second, there are three irregularities in the Romanian “teen” number words that might interfere with some children’s understanding of the pattern: in “unsprezece” (11), “un” is used to represent “1” instead of “unu” (1); in “paisprezece” (14), “pais” is used instead of “patru” (4); and in “saisprezece” (16), “sais” is used instead of “sase.”

However, these variations are comparatively small and more transparent when contrasted with the English number-naming language. For instance, English speakers learn the numeral 11 as “eleven”, 12 as “twelve”, 14 as “fourteen”, 20 as “twenty”, 30 as “thirty” and 45 as “forty-five” where these numbers and words that represent them have different forms in pronunciation and structure connections. For instance, most English speakers are not able see connections from ten to eleven and twelve from a base-10 perspective.

Thus, it can be argued that Chinese oral number naming is the most transparent and consistent with the base-10 system. Romanian number-naming language to a great extent is transparent and consistent with base-10 system while the English number-naming language is least consistent with base-10 pronunciation and structures. Therefore, if the transparency and consistency of base-10 number-naming system determines mathematics performance on tasks related to base-10 knowledge, Romanian children would be expected to be intermediate between Chinese-speaking and English-speaking children in their mathematics performance. The comparison of performance in representing symbolic numbers among Chinese, Romanian, and U.S. children, who have relatively little influences from formal schooling, would help explore the influences of number-naming language on students’ understanding of place values and base-10 systems.

Since the late 1980’s, a series of studies were developed to test the influence of number-naming language on children’s understanding of base-10 systems and thus, relevant mathematics performance. These studies shared two similarities in their research design. First, they all choose pre-school or early elementary students as their participants so that the influence of number-naming language can be presumably isolated from formal schooling and teaching factors. Second, they compared students’ base-10 understanding from high mathematics performing countries where number-naming languages are consistent with base-10 system with students from the lower mathematics performing countries where number-naming language is incongruent with the base-10 system. In this way, the hypothetical relationship between children’s number-naming language, their base-10 understanding, and their mathematics performance can be presumably verified or rejected.

Three types of studies have been conducted following the above research design. The first focuses on single country comparisons. By comparing pre-school children in Taiwan with those in U.S. on abstract counting and object counting, Miller and Stigler (1987) suggested that the Chinese number-naming language, consistent with base-10, favored Chinese children in their object counting while English number-naming language, inconsistent with base-10, did not favor U.S. students in accomplishing abstract counting tasks. Later, Miller et al. (1995) confirmed this findings by comparing children from Mainland China and U.S. Other researchers (Miura & Okamoto, 1989) tested first grade students from Japan and U.S. on their number representation using tens and ones blocks and found that Japanese students performed substantially better than their U.S. counterparts, which is assumed to be contributed by Japanese number-naming language congruent with the base-10 system.

The second type of study includes comparisons between a single country and multiple countries in an attempt to test the assumption across national lines. By comparing U.S. first graders with Chinese, Japanese, and Korean first graders as well as Korean kindergartners on their number representation using tens and ones blocks, Miura and her colleagues (1988) found that U.S. children tended to use ones unit blocks while Chinese, Japanese, and Korean children used correct combinations of tens and ones unit blocks to represent symbolic numbers. The study claimed that Chinese, Japanese, and Korean number-naming languages consistent with base-10 systems contribute positively to their children's performances. Ho and Fuson (1998) tested Chinese preschoolers with different IQ's on their counting sequence, assessed Chinese and U.S. peers on their differences in counting sequence with embedded-ten cardinal understanding, and in the end, compared children from U.S. and England on their embedded-ten cardinal understanding. They found that Chinese children surpassed their English and U.S. peers in rote counting, place value, and embedded-ten cardinal counting and were able to apply this understanding to solve simple addition problems. The researchers proposed that Chinese children's number-naming system influenced these differences in performance rather than their IQ's.

The third type of study includes the comparisons between groups of multiple countries. Miura and her colleagues (1993) repeated their earlier studies by comparing Japanese and Korean first graders with French, Swedish, and U.S. students. Their study concluded that Eastern Asian students with number-naming language consistent with base-10 tended to use more correct combinations of tens and ones blocks to represent symbolic numbers than their Western counterparts whose number-naming languages were inconsistent with the base-10 system. Later, they confirmed this finding by including Chinese first grade students in their comparison and tested all the students in their native language in two consecutive trials (Miura et al., 1994).

All these studies suggest that pre-school or first grade children whose number-naming languages consistent with the base-10 system tend to develop better understanding about place values and base-10 functions than those whose number-naming languages were inconsistent with the base-10 system (Fuson & Kwon, 1991). This implies that the consequence of these place values and base-10 ideas developed among Eastern Asian students may contribute greatly to their learning and performance in the areas of mathematics that rely on a deeper understanding and flexible utilization of place values and a base-10 system (Bloom, 2000; Siegler, 1998).

However, these research findings can be challenged conceptually and methodologically in three ways. First, the use of pre-school and first grade students, although able to control for the influence of formal schooling factors, does not isolate the influence of family and other social factors, such as formal mathematics instruction at home and in preschool environments, from number-naming languages. A longitudinal study (Huntsinger et al., 2000) that followed Chinese-American and Caucasian American children from kindergarten to fourth grade using survey, observation, and interview data, suggested that Chinese-American parents tended to use formal instruction to teach their children mathematics even before they entered schools. An observational and interview study (Yang & Cobb, 1995) also suggested that Chinese first grade students' advantage in composite multiunit numerical concepts can be contributed, in part, to arithmetic learning activities at home and, in part, to their classroom instruction. A reasonable question arising from these studies would be whether the performance difference in base-10 understanding between children from Eastern Asian and U.S. and other Western countries is due to their family and preschool influences or to the additive influences of both family and preschool and number-naming language. To examine this question, comparison of base-10 understanding may be made between children with English as their first and only language and their peers from different racial groups that are influenced by varying culture and family environments, such as that found among Caucasian, Hispanic, and African American children in the U.S. (Ogbu, 1983; Ogbu & Simons, 1994).

Second, the factors that impact preschool and first grade students' understanding of place value and base-10 system may differ substantially since the former presumably have little school influence while the later, although relatively short, may be influenced by teaching that focus on place value and base-10 in early formal schooling. Considering little distinction was made between pre-school children and first grade students in the existing studies, it is reasonable to question whether children's understanding of place values and base-10 systems in Eastern Asian countries is the result of their number-naming language or explicit family and school influences. To address this schooling influence, the question of whether there exists performance differences between preschool and first grade students from countries included in previous comparative studies need to be explored. For instance, were there any differences between preschool and first grade students in China?

Third, the existing studies tend to focus only on the comparison of students in countries who use transparent number-naming languages consistent with base-10 and have higher mathematics performance with those children in the countries where their number-naming language is inconsistent with a base-10 system and possess lower mathematics performances in international comparisons. Little attention is given to the children whose number-naming language are somewhat transparent and consistent with a base-10 system but exhibit lower mathematics performances than those whose number naming language is inconsistent with the base-10 system. Romanian students represent this population since they use a number-naming language that can be classified as being transparent and consistent with the base-10 system except for a few minor irregularities. Nevertheless, Romanian students still scored lower in mathematics performance than both their Asian and U.S. counterparts in international comparisons (Beaton et al., 1996; Mullis et al., 1998; Programme for International Student Assessment, 2004). Countries like Romania limit the interpretative power of the above mentioned language influence research since it is not able to explain why their number-naming language failed to help them perform better in the international comparisons, even though they use a number-naming language that is somewhat consistent with the base-10 system. Alternatively, it may be that the direct relationship between number-naming language consistent with the base-10 system and mathematics performance is weak or does not exist.

To resolve the above three issues, the following question must be answered: Do differences exist in base-10 knowledge among Romanian, East Asian, and U.S. children? This study is designed to examine the aforementioned questions by (1) comparing Romanian, Chinese and U.S. students; (2) examining the differences between kindergarten and first grade students in China, and (3) exploring the differences in base-10 knowledge among Caucasian, African American, and Hispanic students in the U.S.

## METHODOLOGY

### Subjects

To examine and reduce the interactive effects of school factors and number-naming language, both pre-school and first graders early in their formal schooling from China were included. Additionally, first grade children from Romania and U.S. as well as U.S. Caucasians, Hispanic, and African American children were included in order to explore possible differences among different racial groups possessing a similar number-naming language. The U.S. subjects were recruited from two urban elementary schools in a large southwest city. Romania subjects were from an urban area in a large coastal city, and the Chinese subjects were from a suburban area in a large southern city.

There were 20 Chinese subjects (10 preschoolers and 10 first graders; 12 boys and 8 girls) with a mean age of 6.43 yeas old (range = 5 to 7.5 years old). There were 18 first grade Romanian subjects (14 boys and 12 girls) with a mean age of 6.87 years old (range = 6.5 to 7.5 years old). Twenty-six first grade American subjects including 8 Caucasians, 10 African Americans, and 8 Hispanics (14 boys and 12 girls) were selected from the U.S. with a mean age of 6.81 years old (range = 6.5 to 7 years old) and whose first language was English.

**Data collection**

Tests were conducted with all the subjects during the beginning or the first half of their academic year to ensure that school influences on base-10 understanding were minimized. Subjects were individually interviewed in their native language using an identical set of base-10 blocks. These included short blocks representing units of ones and long blocks representing units of tens. The base-10 blocks had not been used during any formal instructional processes with any of the subjects prior to the testing in each country.

Replicating Miura et al's (1994) study, two trials were conducted in this study. During the first trial, researchers met the subjects individually, introduced them to the set of base-10 blocks, and explained that the blocks could be used for counting and constructing numbers. The subjects were then instructed on how to represent three numbers (2, 7, and 15) using correct combinations of base-10 blocks. Each subject was then asked to construct five numbers in the following order: 11, 13, 28, 30, and 42, by using ones and tens blocks. Enough blocks were available so that there would be no constraints for constructing any of the numbers.

In the second trial, immediately following the initial trial, each child was shown and reminded verbally that one tens block was equivalent to 10 single ones blocks. Each subject was then re-taught how to construct representations with the right combination of ones and tens blocks using the number: 2, 7, and 15 as in the first trial. In the end, the subjects were asked to construct the five numbers (11, 13, 28, 30, and 42) in random order.

As in Miura et al's study (1994), each child's responses were scored if they correctly represented the numbers with the right combination of blocks. Correct responses were categorized separately for Trials 1 and 2 using the following categories (Ross, 1986): (1) Unit collection: the representation used only ones blocks. For example, for the number 42, subjects would use 42 ones blocks. (2) Canonical base-10 representation: subject's representation included the correct number of tens blocks and ones blocks with no more than 9 ones blocks in the ones position. For instance, for the number 42, subjects would use 4 tens blocks and 2 ones blocks. (3) Non-canonical base-10 representation: subjects would use the correct number of ten and unit blocks with more than 9 units in the ones place, such as 3 tens blocks and 12 ones blocks for number 42. Each subject's incorrect answers were also calculated and listed along with the different categories of correct answers.

## ANALYSIS AND RESULTS

### Cross-national comparison of number representation

#### *Overall comparison on both trials*

To compare cross-national number representations for each category for both trials, we calculated the mean of each child's responses in each category for both trials. Then, we calculated the percentage of correct representations and incorrect presentations by dividing the possible correct and incorrect representations with actual correct representations in each category and incorrect representations for each national group. The results of this analysis are shown in Table 2, which suggested the following findings:

**Table 2:** Percentage of Representations in Each Category for Both Trials in Each National Group

| Trial 1+2 | N | Unit | Canonical | Non-canonical | Incorrect | Total Correct |
|---|---|---|---|---|---|---|
| China | 20 | 23% | 65% | 12% | 0% | 100% |
| Romania | 18 | 44% | 34% | 15% | 7% | 93% |
| U.S. | 26 | 40% | 38% | 11% | 11% | 89% |

First, Chinese subjects constructed 65% correct representations for canonical base-10 category while Romanian subjects had 34% and the U.S. subjects had 38% in both Trials. These scores indicated that Chinese subjects were more likely to use canonical base-10 to represent numbers than their Romanian and U.S. peers while Romanian and U.S. subjects showed no substantial differences with only a slightly higher percentage for U.S. subjects.

Second, for the unit representation category, Romanian and U.S. subjects showed comparable correct representations (44% and 40%, respectively) which were higher than their Chinese counterparts 23% in both trials. This showed that Chinese subjects were less likely to use unit representations to represent a number than their Romanian and U.S. peers while Romanian and U.S. subjects again showed no differences in this category.

Third, in the non-canonical category, there were no substantial differences across the three national groups with 12%, 15%, and 11% for Chinese, Romanian, and U.S. subjects, respectively. However, U.S. students tended to make more incorrect representations (11%) than Romanian subjects (7%) who had, in turn, more incorrect answers than their Chinese peers (0%).

One-way ANOVA of the three national group means in both trials were conducted for each categorical representation. The means and standard deviations for each national group in using each category of number representations for each trial are shown in Table 3.

**Table 3:** Means and Standard Deviations in Each Category for the Three Groups

| | **China (*n*=20)** | | **Romania (*n*=18)** | | **United States (*n*=26)** | |
|---|---|---|---|---|---|---|
| **Trial 1** | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Unit representations | 1.40 | 1.88 | 2.61 | 2.30 | 2.23 | 1.90 |
| Canonical Base 10 | 2.90 | 3.25 | 1.78 | 1.96 | 2.04 | 1.95 |
| Non-canonical Base 10 | 0.70 | 0.60 | 0.56 | 1.04 | 0.38 | 0.85 |
| Incorrect | 0 | 0 | 0.06 | 0.24 | 0.35 | 0.89 |
| **Trial 2** | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* |
| Unit representations | 0.90 | 1.41 | 1.78 | 1.56 | 1.77 | 1.86 |
| Canonical Base 10 | 3.60 | 1.54 | 1.67 | 1.64 | 1.77 | 1.70 |
| Non-canonical Base 10 | 0.50 | 0.95 | 0.94 | 1.11 | 0.73 | 1.04 |
| Incorrect | 0 | 0 | 0.61 | 1.46 | 0.73 | 1.64 |

*Note: The maximum number possible in each category was 5.*

ANOVA results revealed that there were significant differences for two categories across the three countries: the unit and canonical representations. F-test results revealed F = 6.39 and F= 10.93 for respective unit and canonical representation category, both of which are larger than the F 0.01 (2, 61 df) = 4.98. For the non-canonical and incorrect representations categories, there was no significant difference across the three national groups.

Subsequent to the ANOVA, a post hoc test using the Tukey's Honestly Significant Difference (HSD) was conducted to check the significance of every pairwise difference for the three countries in both the unit and canonical representations. The findings revealed:

First, Chinese subjects performed better in both trials than Romanian and U.S. subjects and at significant level with HSD = 5.86 and HSD = 5.64 respectively, each of which is greater than HSD 0.01 = 3.76. Second, Romanian and U.S. subjects scored higher in using unit representations in both trials than their Chinese peers at significant levels with HSD = 4.63 and HSD = 4.10 respectively, each of which is higher than HSD 0.01=3.76. Third, there were no significant differences between Romanian and U.S. groups in both trials in either the canonical or unit representation categories with HSD = 0.91 and HSD = 0.73 respectively, each of which is smaller than HSD 0.05 = 2.83.

These cumulative results suggest that Chinese subjects tended to use more canonical representations and made fewer incorrect representations while Romanian and U.S. subjects preferred to use unit representations and made more errors to represent numbers, even though there was no significant difference among the three national groups in using non-canonical representations.

### *Comparisons on each trial*

To compare cross-national number representations in each trial for each category, percentages of correct representation in each category and incorrect representation were determined by dividing the possible correct and incorrect representations with actual correct and incorrect representations in each category for each national group for the first trial and then, the second trial. These results are shown in Table 4 which suggest following:

**Table 4:** Percentage of Representations in Each Category for Each Trial in Across Three National Group

| **Trial 1** | **N** | **Unit** | **Canonical** | **Non-canonical** | **Incorrect** | **Total Correct** |
|---|---|---|---|---|---|---|
| China | 20 | 28% | 58% | 14% | 0% | 100% |
| Romania | 18 | 52% | 36% | 11% | 1% | 99% |
| U.S. | 26 | 45% | 41% | 8% | 6% | 94% |
| **Trial 2** | **N** | **Unit** | **Canonical** | **Non-canonical** | **Incorrect** | **Total** |
| China | 20 | 18% | 72% | 10% | 0% | 100% |
| Romania | 18 | 36% | 33% | 19% | 12% | 88% |
| U.S. | 26 | 35% | 35% | 15% | 15% | 85% |

First, Chinese subjects exhibited increasingly more canonical representations (from 58% to 72%) than Romanian and U.S. subjects who showed gradually fewer canonical representations (36 to 33% and 41% to 35%, respectively) from the first trial to the second trial. Second, all three groups reduced their use of unit representations from the first to the second trial with 28% to 18% for Chinese subjects, 52% to 36% for Romanian subjects, and 45% to 35% for U.S. subjects. Third, Chinese subjects used slightly fewer non-canonical representations (14% to 10%) from the first to the second trial while Romanian and U.S. subjects tended to use slightly more non-canonical representations from 11% to 19% and from 8% to 15%, respectively, from the first to the second trial. Fourth, while Chinese subjects did not make any incorrect representations in either trial, Romanian and U.S. subjects tended to make increasingly more incorrect representations from the first trial to second trial (1% to 6% and 12% to 15% correspondently).

F-test results for each representation category in each trial across the three national groups showed a significant difference for only the canonical representation category across the three countries in the second trial. F-test results for the second canonical representation trial revealed $F=11.30$, which is greater than $F\ 0.01\ (2, 61\ df) = 4.98$. Tukey's Honestly Significant Difference analysis revealed that Chinese subjects scored statistically significant better than Romanian and U.S. subjects in the second trial for canonical presentation with $HSD = 5.75$ and $HSD = 5.95$ respectively, each of which is greater than $HSD\ 0.01 = 3.76$. There was no significant difference between Romanian and U.S. subjects in using canonical representations in the second trial with $HSD = 0.32$, which is smaller than $HSD\ 0.05 = 2.83$

Together, these findings suggest that although all three groups learned to use fewer unit representations by the second trial, only the Chinese students increased the use of more canonical representations without mistakes, which differs from their Romanian and U.S. peers at significant level. In contrast, Romanian and U.S. subjects had a tendency to use more non-canonical representations and make more incorrect representations even after repeated demonstration by the researchers.

## Within group comparisons in number representation

*Comparison between two Chinese groups.* The comparison of each categorical number representation between Chinese first grade and preschool subjects in each trial are shown as percentages in Table 5. This table suggests:

**Table 5:** Percentage of Representations in Each Category for Two Chinese Groups

| **Trial 1** | **N** | **Unit** | **Canonical** | **Non-canonical** | **Incorrect** | **Total Correct** |
|---|---|---|---|---|---|---|
| First Grade | 10 | 24% | 70% | 6% | 0% | 100% |
| Pre-School | 10 | 32% | 46% | 22% | 0% | 100% |
| Trial 2 | N | Unit | Canonical | Non-canonical | Incorrect | Total |
| First Grade | 10 | 18% | 78% | 4% | 0% | 100% |
| Pre-School | 10 | 18% | 66% | 16% | 0% | 100% |

First, Chinese first graders constructed 70% canonical representations in the first trial while Chinese preschoolers had only 46%. By the second trial, Chinese first graders' canonical representations increased to 78% while Chinese preschoolers had 66%.

Second, for the unit representation category, Chinese first graders and preschoolers had very small differences in the initial trial (24% and 32%, correspondently). By the second trial, both groups reduced their unit representations to 18%.

Third, Chinese preschoolers tended to use more non-canonical representations than their first grade peers in the first trial (22% and 6%, respectively). By second trial, both group reduced their non-canonical representations to 16% and 4% respectively.

F-test results showed no significant difference between the two Chinese groups in any of the categorical representation across the two trials. F-test results ranged from F= 0.003 to F = 0.642 correspondently, each of which is smaller than $F.05$ (1,18 df) = 4.41.

These findings suggested that although both Chinese groups preferred more canonical representations compared to the other two categories, unit and non-canonical representations, Chinese first graders were more likely to use canonical representations than their preschool peers during the first trial. However, after the demonstration, Chinese preschoolers increased their use of canonical representations substantially as exhibited in their second trial performance. *Comparison among three U.S. groups*. Reminiscent of the three national group analyses, comparisons of each categorical number representation among Caucasian, African American, and Hispanic American groups in the U.S. for each trial were also conducted using percentages. These results shown in Table 6 suggest the following:

**Table 6:** Percentage of Representations in Each Category for Three U.S. Groups

| **Trial 1** | **N** | **Unit** | **Canonical** | **Non-canonical** | **Incorrect** | **Total Correct** |
|---|---|---|---|---|---|---|
| Caucasian Americans | 8 | 43% | 35% | 0% | 23% | 77% |
| African Americans | 10 | 50% | 34% | 16% | 0% | 100% |
| Hispanic Americans | 8 | 40% | 55% | 5% | 0% | 100% |
| **Trial 2** | **N** | **Unit** | **Canonical** | **Non-canonical** | **Incorrect** | **Total Correct** |
| Caucasian Americans | 8 | 25% | 33% | 10% | 33% | 67% |
| African Americans | 10 | 36% | 42% | 10% | 12% | 88% |
| Hispanic Americans | 8 | 45% | 30% | 25% | 0% | 100% |

First, Caucasian and African American subjects preferred to use unit representations rather than canonical or non-canonical alternatives (43% and 50%, respectively). In contrast, Hispanic subjects preferred to use canonical representation (55%) rather than the other two representations during the initial trial.

Second, by the second trial, Caucasian and African American subjects tended to use canonical more than the other representational options (33% and 42%, respectively), while Hispanic American subjects preferred to use unit representation more (45%).

Third, all three U.S. groups tended to use fewer non-canonical representations than the other two representational options as shown by 0% for Caucasians, 16% for African Americans, and 5% for Hispanic Americans in the first trial. However, by the second trial, Caucasian and Hispanic American subjects increased their use of non-canonical representation (10% and 25%, respectively) while African American subjects reduced their use of this representation (10%).

Fourth, while Hispanic subjects made no incorrect representations in both trials which are similar to their Chinese counterparts, Caucasian and African American subjects increased their incorrect representations from the first to the second trials (23% to 33% and 0% to 12%, respectively). In addition, the Caucasian group made the most incorrect representations among all three groups in both trials.

F-test results for each categorical representation showed that there were significant differences among the three U.S. groups in using non-canonical representation and making incorrect representations in the initial trial. F-test results for the first non-canonical representation trial revealed $F = 3.96$, which is larger than $F_{.05}$ (2, 23 df) = 3.42. For the first incorrect representation trial, $F=6.26$, which is greater than $F_{.01}$ (2, 23 df) = 5.66. Tukey's Honestly Significant Difference analysis revealed that African American subjects were more likely than their Caucasian peers to use non-canonical representations at statistically significant levels during the initial trial with HSD=3.11, which is larger than HSD 0.05= 2.92. Caucasian subjects were more likely than African and Hispanic American subjects to make errors during the first trial at statistically significant level with HSD=4.48 and HSD= 4.25 respectively, each of which is greater than HSD 0.01= 3.96. In addition, these findings also suggested that the repeated demonstration by the researcher had different effects on their use of canonical representations

## DISCUSSION AND CONCLUSION

This study was conducted with two foci in mind. The first was to determine whether children in China, Romania, and U.S. had different levels of base-10 knowledge. The second was to examine whether there were differences between Chinese pre-school and first grade children and among different U.S. racial groups in light of base-10 knowledge. Our exploration is to help further scrutinize the assumptions made about the influences of structural characteristics of particular numerical languages on children's number representations, which may, in turn, explain the variations seen in mathematics understanding and performances in international comparisons.

Findings from the comparisons of the three national groups suggested that, on the one hand, Chinese children outperformed both Romanian and U.S. children in using base-10 systems and Chinese children's performance in this area increased substantially as they progressed from the first to the second trial. On the other hand, Romanian and U.S. children were not different from each other in using the base-10 system. Instead, they both preferred to use unit representations and even after repeated instruction, they both failed to yield any substantial gains in their base-10 task performance. These findings not only support the claim that the intuitive influence of language structure on specific thinking process is weak in the field of linguistics (Gumperz & Levinson, 1996; Rasmussen, 2006), but also challenge the assumed relationship between number-naming language and student understanding of base-10 knowledge and consequential mathematics performance in several ways.

First, the Romanian number-naming language is somewhat transparent and consistent with the base-10 system. It is intermediate between Chinese and English number-naming languages. Although such language features helped to explain why Romanian children did not perform as well as Chinese peers, it failed to explain why Romanian children did not perform better in place values and base-10 tasks than their U.S. peers who were presumably disadvantaged with their number-naming language.

Second, Chinese pre-school children tended to use substantially fewer canonical representations than their first grade peers in first trial but with repeated instruction in the second trial, they significantly increased their performance. This finding suggests that even a short period of schooling may possibly affect children performance on base-10 tasks, which leads to further questions about the possible differences that exist between preschoolers and first grade children in the Eastern Asian countries and which deserve future research exploration. The finding seems to suggest that instead of exerting influence on children's performance in base-10 tasks in a habitual manner, the influence of number-naming language may need to be activated by activities with a clear intention.

Third, while helping Chinese children produce more canonical representations, the instruction given in the second trial did not seem to help produce more canonical representations for the Romanian children over their U.S. counterparts. These findings are surprising considering that both Chinese preschoolers and Romania children share some similarities in number-naming language advantages than U.S. participants. Thus, this raises the question of whether number-naming language advantages can be activated to help children perform better in using base-10 knowledge without considering the impact of other influential factors, such as family and other social influences outside of schools.

The exploration of the differences within each group also revealed some interesting findings. These findings came from the comparison among the three U.S. groups during their first trial. First, African American and Caucasian students tended to have similar levels of canonical 10 performances. Second, African American students were more likely than their Caucasian peers to use non-canonical representations. Third, Hispanic American students tended to use more canonical representations than both their African American and Caucasian peers while Caucasian students tended to make the most incorrect representations. These differences among the three is reminiscent of the findings in the 1980's that showed that the failure of African American children to perform well in mathematics was not necessarily due to their lack of informal mathematics knowledge developed in their home or cultural environments. Rather, it may be that their informal mathematics knowledge may not be enhanced in school learning (Ginsburg & Allardice, 1984). Thus, further comparisons among the different racial groups within the U.S. context are valuable not only for verifying the language influences on mathematics learning but also for a deeper understanding about the various levels and ways of understanding base-10 knowledge among different groups.

As implied previously, one of the major limitations in our study is the use of small sample sizes. Because of this, generalization of our findings is limited. However, our study extends the same line of inquiry and provides a check on the reliability of previous studies. As well, the limitation in sample sizes is also prevalent in all of the previously conducted studies in this area that often use fewer than 100 children in each groups in the comparison. Future research should focus on greater sample sizes and more refined comparisons between and within national groups. Another limitation of these studies, also found in our present study, is the experimental treatment itself. The type of treatment used may prevent researchers from directly exploring the relationship between number-naming language structure and mathematics. This is shown in two recent studies which reported that a simple addition of twenties blocks to the tens and ones blocks used in the experimental process (Towse & Saxton, 1997) or a change in the numbers used in the demonstration part of the treatment (Alsawaie, 2004) may cause substantial differences in the use of canonical representation for children whose number-naming languages are not consistent with the base-10 system. Thus, instead of settling the debate about the relationship between language structures and mathematics learning, this study can serve as an inspiration for future studies to use more creative research designs for more discriminating comparisons in this area.

**REFERENCES**

Alsawaie, O. N. (2004). Language influence on children's cognitive number representation. *School Science & Mathematics, 104*(3), 105-111.

Beaton, A. E., Mullis, L., Martin, M., Gonzalez, E., Kelly, D., & Smith, T. (1996). *Mathematics achievement in the middle school years. IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Bell, G. (1990). Language and counting: Some recent results. *Mathematics Education Research Journal, 2*(1), 1-14.

Bloom, P. (2000). *How children learn the meanings of words.* Cambridge, MA: MIT Press.

Chen, C., & Stevenson, H. W. (1995). Motivation and mathematics achievement: A comparative study of Asian-American, Caucasian-American, and East Asian high school students. *Child Development, 66*(4), 1215-1234.

Chiu, L. H. (1987). Locus of control in intellectual situations in American and Chinese school children. *International Journal of Psychology, 21*, 167-176.

Cohen, D. K., & Spillane, J. P. (1992). Policy and practice: The relations between governance and instruction. *Review of Research in Education, 18*, 3-49.

Crystal, D. S., & Stevenson, H. W. (1991). Mothers' perceptions of children's problems with mathematics: A cross-national comparison. *Journal of Educational Psychology, 83*(3), 372-376.

Eckstein, M. A. (1993). *Secondary school examinations: International perspectives on policies and practice*. New Haven, CT: Yale University Press.

Flynn, J. R. (1991). *Asian Americans: Achievement beyond IQ*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Fuson, K. C., & Kwon, Y. (1991). Chinese-based regular and European irregular systems of number words: the disadvantages for English-speaking children. In, K. Dunkin &B. Shire, (Eds.), *Language in Mathematical Education: Research and Practice*. Philadelphia, PA: Open University Press.

Geary, D. C. (1996). International differences in mathematical achievement: Their nature, cause, and consequences. *Current Directions in Psychological Science, 5*(5), 133-137.

Geary, D. C., Bow-Thomas, C. C., Liu, F., & Siegler, R. S. (1993). Even before formal instruction, Chinese children outperform American children in mental addition. *Cognitive Development, 8*(4), 517-529.

Ginsburg, H. P., & Allardice, B. S. (1984). Children's difficulties with school mathematics. In B. Rogoff & J. Lave (Eds.), *Everyone cognition: Its development and social context* (pp. 194-219). Cambridge, MA: Harvard university Press.

Gumperz, J., & Levinson, S. C. (1996). Introduction: linguistic relativity re-examined. In J. Gumperz & S. C. Levinson (Eds.), *Rethinking linguistic relativity* (pp. 1-18). Cambridge, UK: Cambridge University Press.

Han, Y., & Ginsburg, H. P. (2001). Chinese and English mathematics language: The relation between linguistic clarity and mathematics performance. *Mathematical Thinking and Learning, 3*(2-3), 201-220.

Hess, R. D., & Others. (1987). Cultural variations in family beliefs about Children's performance in mathematics: Comparisons among the People's Republic of China, Chinese-American, and Caucasian-American families. *Journal of Educational Psychology, 79*(2), 179-188.

Ho, C. S., & Cheng, F. S. (1997). Training in place-value concepts improves children's additional skills. *Chinese University of Hong Kong, 22*, 495-506.

Ho, C. S. H., & Fuson, K. C. (1998). Children's knowledge of teen quantities as tens and ones; Comparisons of Chinese, British, and American kindergartners. *Journal of Educational Psychology, 90*(3), 536-544.

Huntsinger, C. S., Jose, P. E., Larson, S. L., Krieg, D. B., & Shaligram, C. (2000). Mathematics, vocabulary, and reading development in Chinese American and European American children over the primary school years. *Journal of Educational Psychology, 92*(4), 745-760.

Kaufman, P., Chavez, L., & Lauen, D. (1998). *Generational status and educational outcomes among Asian and Hispanic 1988 eighth graders. National postsecondary student aid study: 1995-96.* (Statistical Analysis Report No. NCES 1999-020). Washington, DC: Department of Education, Office of Educational Research and Improvement.

Leung, F. K. S. (2002). Behind the high achievement of East Asian students. *Educational Research and Evaluation: An International Journal on Theory and Practice, 8*(1), 87-108.

Lewis, C. C. (2000). *Lesson study: The core of Japanese professional development.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Li, C., & Nuttall, R. (2001). Writing Chinese and mathematics achievement: A study with Chinese-American undergraduates. *Mathematics Education Research Journal, 13*(1), 15-27.

Lucy, J. A. (1996). The scope of linguistic relativity: An analysis and review of empirical research. In J. Gumperz & S. C. Levinson (Eds.), *Rethinking linguistic relativity* (pp. 37-69). Cambridge, UK: Cambridge University Press.

Lynn, R. (1991). Race differences in intelligence: A global perspective. *Mankind Quarterly, 31*(3), 255.

Ma, L. (1999). *Knowing and teaching elementary mathematics*. Mahwah, New Jersey: Lawrence Erlbaum associates, Publishers.

Mayer, R. E., Barbara, S., & Tajika, H. (1995). A comparison of how textbooks teach mathematical problem solving in Japan and the United States. *American Educational Research Journal, 32*(2), 443-460.

Michael, L. (2002). Reformulating the Sapir-Whorf hypothesis: Discourse, interaction, and distributed cognition. *Texas Linguistic Forum, 45*, 107-116.

Miller, K. F., Major, S. M., Shu, H. & Zhang, H. (2000). Ordinal knowledge: number names and number concepts in Chinese and English. *Canadian Journal of Experimental Psychology, 54* (2), 129-139,

Miller, K. F., Smith, C. M., Zhu, J., & Zhang, H. (1995). Preschool origin of cross-national differences in mathematics competence. *Psychological Science, 6*(1), 56-60.

Miller, K. F., & Stigler, J. W. (1987). Counting in Chinese: Cultural variation in a basic cognitive skills. *Child Development* (2), 279-305.

Miura, I. T., Kim, C. C., Chang, C. M., & Okamoto, Y. (1988). Effects of language characteristics on children's cognitive representation of number: Cross-national comparisons. *Child Development, 59*(6), 1445-1450.

Miura, I. T., & Okamoto, Y. (1989). Comparisons of U.S. and Japanese first-graders' cognitive representation of number and understanding of place value. *Journal of Educational Psychology, 81*(1), 109-113.

Miura, I. T., Okamoto, Y., & Kim, C. C. (1994). Comparisons of children's cognitive representation of Number: China, France, Japan, Korea, Sweden, and the United States. *International Journal of Behavioral Development, 17*(3), 401-411.

Miura, I. T., Okamoto, Y., Kim, C. C., Steere, M., & Fayol, M. (1993). First graders' cognitive representation of number and understanding of place value: Cross-national comparisons-France, Japan, Korea, Sweden, and the United States. *Journal of Educational Psychology, 85*(1), 24-30.

Mullis, I. V. S., Martin, M. O., Beaton, A. E., Gonzalez, E. J., Kelly, D. L., & Smith, T. A. (1997). *Mathematics achievement in the primary school years: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Beaton, A. E., Gonzalez, E. J., Kelly, D. L., & Smith, T. A. (1998). *Mathematics and science achievement in the final year of secondary school: IEA's Third International Mathematics and Science Study (TIMSS)*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., & Chrostowsk, K. M. (2004). *TIMSS 2003 International Mathematics Report: Findings from IEA's trends in international mathematics and science study at the fourth and eight grades*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Gregory, K. D., Garden, R. A., O'Connor, et al. (2000). *TIMSS 1999 international mathematics report: Findings from IEA's repeat of the Third International Mathematics and Science Study at the eight grade*. Chestnut Hill, MA: TIMSS International Study Center, Boston College.

Ogbu, J. U. (1983). Minority status and schooling in plural societies. *Comparative Education Review, 27*(2), 168-190.

Ogbu, J. U., & Simons, H. D. (1994). *Cultural models of school achievement: A quantitative test of Ogbu's theory* (A Comparative Study No. Project 12). Berkeley, California: University of California at Berkeley.

Patterson, M., Perry, E., Decker, C., Eckert, R., Klaus, S., Wendling, L., et al. (2003). Factors associated with high school mathematics performance in the United States. *Studies in Educational Evaluation, 29*(2), 91-108.

Perry, M. (2000). Explanations of mathematical concepts in Japanese, Chinese, and U.S. first- and fifth-grade classrooms. *Cognition and Instruction, 18*(2), 181-207.

Programme for International Student Assessment. (2004). *First results from PISA 2003: Executive summary*. Paris, France: Organization for Economic Cooperation and Development.

Rasmussen, c., Ho, e., Nicoladis, E., Leung, J. & Bisanz, J. (2006). Is the Chinese number-naming system transparent? Evidence from Chinese-English bilingual children. *Canadian Journal of Experimental Psychology, 60(1)*, 60-67.

Romberg, T. A. (1997). The influence of programs from other countries on the school mathematics reform curricula in the United States. *American Journal of Education, 106*(1), 127-147.

Romberg, T. A. (1999). School mathematics: The impact of international comparisons on national policy. In G. Kaiser, E. Luna & L. Huntley (Eds.), *International comparison in mathematics education* (pp. 189-199). Philadelphia, PA: Falmer Press.

Ross, S. H. (1986). *The development of children's place-value numeration concepts in grades two through five.* Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Sanchez, K., Kellow, T., & Ye, R. (2000, April 24-28). *A comparison of Stanford Achievement Test (SAT-9) performance across grade, gender, ethnicity, and educational program placement.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Sapir, E. (1949). *Culture, Language and Personality*. Berkeley, CA: University of California Press.

Schmidt, W., Jorde, D., Cogan, L. S., Barrier, E., Gonzalo, I., Moser, U., et al. (1996a). *Characterizing pedagogical flow: An investigation of mathematics and science teaching in six countries*. Dordrecht: The Netherlands Klewer Publishing.

Schmidt, W. H., McKnight, C. C., Cogan, L. S., Jakwerth, P. M., & Houang, R. T. (1999). *Facing the consequences*. Boston: Kluwer Academic Publishers.

Schmidt, W. H., McKnight, C. C., & Raizen, S. A. (1996b). *A splintered vision: An investigation of U.S. science and mathematics education*. Dordrecht, Boston, London: Klumer Academic Publishers.

Siegler, R. (1998). *Children's thinking (* 3rd ed.). New York, NY: Prentice Hall.

Stevenson, H. W., Chen, C., & Lee, S. (1993). Motivation and achievement of gifted children in East Asia and the United States. *Journal for the Education of the Gifted, 16*(3), 223-250.

Stevenson, H. W., Lee, S.-y., Chen, C., & Lummis, M. (1990). Mathematics achievement of children in China and the United States. *Child Development, 61*(4), 1053-1066.

Stigler, J. W., & Hiebert, J. (1999). *Teaching gap*. New York, NY: The Free Press.

Stigler, J. W., Lee, S. Y., & Stevenson, H. W. (1987). Mathematics classrooms in Japan, Taiwan, and the United States. *Child Development, 58*(5), 1272-1285.

Stigler, J. W., Lee, S. Y., & Steven, H. W. (1990). *Mathematical Knowledge of Japanese, Chinese, and American Elementary School Children*. Reston, VA: National Council of Teachers of Mathematics.

Takasugi, S. (2006) A playground of thought: Number Systems of the World. [Electronic version]. Retrieved October 20, 2006, from http://www.sf.airnet.ne.jp/ts/language/number.html

Towse, J. N., & Saxton, M. (1997). Linguistic influence on children's number concepts: Methodological and theoretical considerations. *Journal of Experimental Child Psychology, 66*, 362-375.

Tuss, P., Zimmer, J., & Ho, H. Z. (1995). Causal attributions of underachieving fourth-grade students in China, Japan, and the United States. *Journal of Cross-Cultural Psychology, 26*(4), 408-425.

Wang, J. (2001). Contexts of mentoring and opportunities for learning to teach: A comparative study of mentoring practice. *Teaching and Teacher Education, 17*(1), 51-73.

Wang, J., & Lin, E. (2005). Comparative studies on U.S. and Chinese mathematics learning and the implications for standards-based mathematics teaching reform. *Educational Researcher, 34*(5), 3-13.

Wang, J., & Paine, L. W. (2003). Learning to teach with mandated curriculum and public examination of teaching as contexts. *Teaching and Teacher Education, 19*(1), 75-94.

Whorf, B. L. (1956). *Language, Thought and Reality*. London, England: Chapman and Hall.

Wilkins, J. L. M. (2004). Mathematics and science self-concept: An international investigation. *Journal of Experimental Education, 72*(4), 331-346.

Yang, M. T. L., & Cobb, P. (1995). A cross-cultural investigation into the development of place-value concepts of children in Taiwan and the United States. *Educational Studies in Mathematics, 28*(1), 1-33.

Author : **Wang, Jian**

E-mail : wangj2@unlv.nevada.edu

Address : 4505 Maryland Parkway. Box 453005
Las Vegas, NV 89154-3005

Author : **Emily Lin**

E-mail : emily.lin@unlv.edu

Address : 4505 Maryland Parkway. Box 453005
Las Vegas, NV 89154-3005

Author : **Madalina Tanase**

E-mail : tanasem@unlv.nevada.edu

Address : 4505 Maryland Parkway. Box 453005
Las Vegas, NV 89154-3005

Author : **Midena Sas**

E-mail : mmsas@unlv.nevada.edu

Address : 4505 Maryland Parkway. Box 453005
Las Vegas, NV 89154-3005