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A Study of Number Sense Performance among Low-SES Students, New Immigrant Children, and Typical Learners in Grades Four Through Six

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To examine the relative performance in number sense among low-SES students, new immigrant students, and typical learners in grades 4 through 6, data were collected through a number sense web-based, two-tier test. A total of 628 fourth graders, 535 fifth graders, and 524 sixth graders in Taiwan participated in this study. Results showed that there were statistically significant differences in number sense performance among new immigrant children, low-SES students, and typical learners in the fourth, fifth, and sixth grades. The subsequent post hoc comparisons indicated that there was a statistically significant difference between typical learners and new immigrant children in fourth and fifth grades. Moreover, there were statistically significant differences between typical learners and low-SES students in fifth and sixth grades. The Chi-squared test results also showed that there were significant differences in the uses of solution methods between the fourth, fifth, and sixth graders. Implications of this study and suggestions for the future studies are discussed.

Keywords: Grades 4-6, low-SES students, new immigrant children, number sense, typical learners.

INTRODUCTION

Equity in access to mathematics resources for all students has been internationally considered as an important issue in mathematics education (Atweh, Vale, & Walshaw, 2012; Ministry of Education in Taiwan [MET], 2010; Nasir & Cobb, 2007; National Council of Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 2004; Oakes, Joseph, & Muir, 2004) over the past 10 years. For example, NCTM's Principles and Standards for School Mathematics (2000) states, "Excellence in mathematics education requires equity—high expectations and strong support for all students" (p. 11). This underscores the importance of research on equity in mathematics education. Especially students from low social economic status (low-SES) need more help in mathematics learning (Chen, Yang, Yao, & Lai, 2008; Yao & Yang, 2010).

Furthermore, helping children develop number sense has been emphasized internationally in many studies and reports (Berch, 2005; Dunphy, 2007; NCTM, 2000; Jordan, Raminent, & Watkin, 2010; Sood & Jitendra, 2007; Verschaffel, Greer, & De Corte, 2007; Yang & Li, 2013; Yang & Wu, 2010). For example, the Number and Operations Standard in Principles and

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State of the literature

- Number sense plays an important role in elementary school mathematics education.
- Currently, there is no study focusing on the examination of differences on the number sense performance among Low-SES students, New immigrant children and Typical learners.
- Number sense is an important indicator of future mathematics learning and achievement for students

Contribution of this paper to the literature

- Be able to understand the differences on number sense performance among new immigrant children, low-SES students, and typical learners for fourth, fifth, and sixth graders.
- The findings show the need to improve the low-SES students' number sense in grade four, five, and six.
- New immigrant children perform better than typical learners and low-SES students in grade six and perform better than low-SES students in grade five.

Standards for School Mathematics (NCTM, 2000) emphasizes that "central to this standard is the development of number sense" (p. 32). This further indicates the importance of number sense. Earlier studies showed that SES is a key factor to success in school. Moreover, studies showed that high- and middle-SES children generally outperform children from low-SES families on mathematics performance (Kern, 2012; Morgan, Farkas, Hillemeier, & Maczuga, 2009; Starkey, Klein, & Wakeley, 2004) due to the fact that low-SES students are lacking of learning opportunities and low motivation. New immigrant children also perform poor than typical learners in Taiwan because they are lacking of learning opportunities (Chen et al., 2008). In addition, the study of Yang, Li, and Lin. (2008) showed that there was a significant correlation between students' achievements in mathematics and number sense. The findings of previous studies (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan et al., 2010; Dyson, Jordan, & Glutting, 2013; Wright, Stanger, Cowper, & Dyson, 1996) suggest that number sense development of earlier grades is an important predictor for their later mathematics learning. Previous studies also indicated that poor mathematics outcomes for low-SES children are mediated by weak number sense (Jordan et al., 2009; Jordan & Glutting, 2010). Children from high- and middle-SES tend to develop number sense better in preschool years than low-SES children (Griffin, Case, & Siegler, 1994). Therefore, the number sense development at earlier grades may affect low-SES students, new immigrant children, or typical learners in their future mathematics learning. In this study, we first define the new immigrant children as their mothers being immigrants such as from Vietnam, Indonesia, Thailand, Philippines, or Mainland China while their father are Taiwanese (Hsin, 2010; MET, 2010). Next, Low-SES students in this study refer to children from low-income families, chtableildren from single-parent families, and those who have grandparents as guardians (MET, 2010) excluding new-immigrant children who are also belonging to low-SES. Students who do not belong to the new immigrant children and the low-SES students are defined as typical learners.

Currently, about 7% of children in grades 1–9 in Taiwan are new immigrant children (MET, 2010). The percentage of new immigrant children has continued to increase in the past few years. In addition, there are many low-SES students in grades 1–9. Although there are more and more disadvantaged children in Taiwan, at the same time, the findings of PISA (Organization for Economic Co-operation and Development [OECD], 2009) showed that 15-year-old students in Taiwan received the highest scores on their mathematics assessment. From this contradictory comparison, we can notice that we have high achievement students but low achievement students exist mostly. Providing equal opportunity to learn and develop is necessary for all students. Therefore, examining the differences on number sense performance among new immigrant children, low-SES students (including students from low income families, single-parent families, and grandparents as guardians) and typical learners can be of great help to teachers as well as to educational administrators. Accordingly, the research questions for this study are as follows:

1. Are there significant differences in number sense performance among low-SES students, new immigrant children, and typical learners?

2. Do low-SES students, new immigrant children, and typical learners use different solution methods to solve number sense problems?

BACKGROUND

New Immigrant Children and Disadvantaged Children in Taiwan

Because of their lower economic status, men residing in rural areas or fishing villages have found it difficult to marry a Taiwanese wife (Mo & Lai, 2004; Yao, 2009). A family composed of a new immigrant mother (from Vietnam, Indonesia, Thailand, Philippines, or Mainland China) and a Taiwanese father is called a new immigrant family (Hsin, 2010). In Taiwan, the children from these families are called new

immigrant children (Peng, 2007). Currently, about 7% of children in grades 1–9 in Taiwan are new immigrant children (MET, 2010), and this number has continued to grow.

Low-SES students in this study include children from low-income families, children from single-parent families, and those who have grandparents as guardians. The percentage of divorce has increased from 6.5% to 11.1%, and the number of low-income families also increased greatly from 2005 to 2009 in Taiwan (Ministry of Interior in Taiwan, 2010). As a result, the number of low-SES students has increased substantially in the past five years.

New Immigrant Children and Low-SES students' Related Studies

Several studies (Chang, 2005; Doctoroff, 2001) show that new immigrant children often encounter difficulties in adapting to a new environment, which affects their school achievement; other studies (Gee, 2004; Hsiao, 2009; Kilbride & Ali, 2010; Mendoza, 2002; Seah, Atweh, Clarkson, & Ellerton, 2008) indicate there are language barriers that limit their learning opportunities. Also, these students often lack positive attitudes due to language and cultural barriers and low socioeconomic status (MET, 2010; Sreeharsha, 2010). These situations show that these new immigrant children are the newly disadvantaged group in Taiwan (Mo & Lai, 2004; Tan & Wu, 2009). New immigrant children are often at a considerably disadvantaged compared to their peers at school (Bohlmark, 2009; Crosnoe, 2005; Kao & Rutherford, 2007; Schnepf, 2007). However, the study of Chen (2010) indicates that there is no significant difference on learning achievement between native-born parents and foreign-born mother with native-born father. In addition, it is unclear how new immigrant children perform more poorly than their peers at schools in Taiwan. Researchers have not reached agreement as to the degree of learning disadvantages these children face. Learning more about the issues that new immigrant children face will help school representatives provide the needed services that can enhance their learning (Birman, Weinstein, Chan, & Beehler, 2007; Miller, 2009; Wang, Young, & Smith, 2009).

Several earlier studies (Arnold & Doctoroff, 2003) found that children with socioeconomic disadvantages experienced a high degree of failure in their academic achievement. Arnold and Doctoroff found that poor mathematics trajectories in low-SES children began very early and, therefore, this phenomenon should receive specific attention early so that sufficient resources may be found to help reduce this SES-related gap. Indeed, SES is a powerful predictor of children's academic performance (Pogrow, 2009). Several studies have shown that children from poor families have more difficulty in learning mathematics compared with their school peers (Chen et al., 2008; Yao & Yang, 2010). Most teachers in Taiwan agree that these low-SES students need more attention and academic assistance; however, research has not focused on this issue in the field of mathematics education (Chen et al., 2008; Cramer, Post, & delMas, 2002; Empson, 2003; NCTM, 2000). If mathematics educators want to help all students attain a high level of mathematics achievement, we need to pay more attention to low-SES students in mathematics classrooms (Deschenes, Cuban, & Tyack, 2001; NCTM, 2000; NRC, 2001; Rodriguez, 2005).

Number Sense

Number sense can be defined as a person's understanding of number, operations, and the relationship between number and operations, and the ability to apply flexible and efficient methods to solve situated problems that include numbers (Berch, 2005; Carboni, 2008; Jordan, Kaplan, Oláh, & Locuniak, 2006; Kaminski, 2002; NCTM, 2000). Based on number sense related studies (McIntosh, Reys, & Reys, 1992; Reys & Yang, 1998; Yang & Wu, 2010), this study defined number sense components as (a) understanding the meanings of numbers, operations, and their relationships; (b) recognizing the relative magnitude of numbers; (c) being able to compose and decompose numbers flexibly; (d) recognizing the relative effect of operations on numbers; and (e) judging the reasonableness of a computational result via different methods.

The Role of Number Sense in Mathematics Learning

Many researchers have observed a highly significant positive correlation between number sense and mathematics achievement (Halberda, Mazzocco, & Feigenson, 2008; Jordan et al., 2010; Schneider, Grabner, & Paetsch, 2009; Yang et al., 2008). Number sense, most strongly related to the ability to solve applied mathematics problems in various contexts (Jordan, Glutting, & Ramineni, 2010), may have relevant implications for children with mathematical disabilities (Berch, 2005; Jordan et al., 2007). Having good number sense can improve higher-order thinking (Geary, Bow-Thomas, & Yao, 1992), but unstable number sense can lead to fatigued calculation or mathematical learning difficulties (Gersten, Jordan, & Flojo, 2005; Mazzocco & Thompson, 2005). Therefore, number sense is the foundation for learning formal mathematics concepts and skills in elementary schools (Jordan et al., 2007). At the same time, developing good number sense helps children to appreciate and enjoy numerical concepts and

to demonstrate more confidence in themselves (Carboni, 2008). Number sense is an important indicator of future mathematics learning and achievement for students (Jordan et al., 2007).

METHOD

Participants

A total of 628 fourth graders, 535 fifth graders, and 524 sixth graders in 23 classes, 22 classes, and 21 classes, respectively, from 15 elementary schools in Taiwan participated in this study. They were selected from a broad range of family backgrounds, including various parental occupations, incomes, and educational levels. The distributions of fourth, fifth, and sixth graders for the three different groups are presented in Table 1.

Instruments

Web-based two-tier tests for fourth, fifth, and sixth graders' number sense were used to collect data (Yang, 2010). Web-based two-tier test implies that the first-tier test examines students' responses to number sense-related questions, and the second-tier test investigates students' reasons for their related choice made in the first-tier test. The two-tier tests for fourth, fifth, and sixth graders respectively include 32, 40, and 50 items. The results of previous tests show that their Cronbach α's are .828, .800, and .877. The difficulty indices of the test items for fourth grade are between .26~.67, for fifth grade between.25~.72, and for sixth grade between.26~.79. The discrimination powers are between .48~.80, .26~.77, and .22~.77 for the three grades, respectively. The above empirical evidence shows that the instruments have good reliability.

The test's validity covers the content validity, specialist validity, and construct validity. To ensure the designed items were representative and not beyond the curriculum scope usually taught to fourth, fifth, and sixth graders in Taiwan, nine elementary school teachers and two mathematics educators were invited to review test items of rating the degree to which the item taps are objective (Aiken, 1985). Questionnaire survey method was used to collect data from 11 experts used a four point Likert scale to judge the appropriateness of each item in this study. The results indicated that content validity coefficient for each item ranged from .80 to .95; meanwhile, homogeneity reliability coefficient ranged from .67 to 1. A high coefficient value with significant level indicated that the whole scale or each item had high content validity and homogeneity reliability. Additionally, Construct validity appeared to be good for the factor loadings ranging between .62~ .83, and the construct reliability indices derived from SEM analysis (structural equation modeling) are .875, .801, and .897, respectively, for fourth, fifth, and sixth grade tests. Therefore, the scales used in this study were representative and appropriate in terms of the item content for fourth, fifth, and sixth graders.

Table 1. Descriptive Statistics for the Three Different Groups of Students in Fourth, Fifth, and Sixth Grades

	Number of students	Male	Female
Fourth graders			
Low-SES students	94	46	48
New immigrant children	69	35	34
Typical learners	465	250	215
Fifth graders			
Low-SES students	66	29	37
New immigrant children	50	27	23
Typical learners	419	213	206
Sixth graders			
Low-SES students	94	51	43
New immigrant children	40	20	20
Typical learners	390	206	184

Table 2. Scoring Scheme for the Number Sense Test

Answer	Correct				Wrong
First-tier test scores	4 points				0 Point
Reason	NS-Based	Rule-Based	Misconceptions	Guess	0 Point
Second-tier test scores	4 points	2 points	1 point	0 points	0 Point
Two-tier test scores	8 points	6 points	5 points	4 points	0 Point

Procedure

Due to the time constraint of a 40-minute class period and the limited attention span of children, the test questions for each grade were equally divided into two parts (40 minutes per section). The following procedure was used to administer the two-tier test for number sense:

1. Log on to the on-line testing system.
2. Key in personal information.
3. Display testing rules.
4. Display one practice item for the students.
5. Administer the formal Web-based two-tier test items (see Appendix I).

Scoring and Analyzing

The scoring method was the same for each grade. Because the test used multiple-choice items, the students were required to provide a correct answer and a reason for the given answer. The scoring scheme for the test is detailed in Table 2.

We believe that the application of number sense is of equal importance to providing the correct answer because appropriate use of number sense is a good indicator of effective thinking. Therefore, students with the appropriate application of number sense and the correct answer receive an identical score of 8 points. A student's response pattern including correct answer and the corresponding rule-based reason receive 6 points. If a misconception-based reason follows a correct answer, 5 points are given. Under the correct answer, students with a guess-based reason response pattern are given 4 points. However, if the answer is wrong, respondents receive 0 points, no matter which type of reason is given.

Normality and Sample Independence between Low-SES and New Immigrant Children

There are three assumptions in ANOVA analysis: normality, independence, and constant variance. In the first place, the one-way ANOVA, tolerating violations to its normality assumption rather well, is considered a robust test against the normality assumption (Khan & Rayner, 2003). Simultaneously, ANOVA is relative immune to violations in the normality assumption when the sample sizes are large. For moderately large samples and the one-way ANOVA test adopted in the study, it is relatively robust to moderate violations of the normality assumption. Besides, the study applied the Durbin–Watson statistic to detect the presence of autocorrelation between three background variables. The results shows Durbin-Watson equals to 1.8, 1.7, and 1.8 for fourth, fifth, and sixth grade. Based on the Durbin-Watson statistic ranges in value from 0 to 4, a value near 2 indicates non-autocorrelation, a value toward 0 indicates positive autocorrelation, and a value toward 4 indicates negative autocorrelation (Durbin & Watson, 1971). This test verifies the relationship between background variables is separated from each other. Finally, the test for the assumption of homogeneity of variance will be shown in the chapter of result in the study.

RESULTS

The Difference of Students' Number Sense Performance among Three Groups

Table 3 reported the descriptive statistics on number sense performance for three groups of students by student type. For fourth-grade students, the mean number sense scores were from the highest to the lowest: typical learners, low-SES students, and new immigrant children. The mean scores from the highest

Table 3. Descriptive Statistics of Number Sense Performance for Different Groups in 4 to 6 Grades

4th-graders			
Different groups	Mean scores	Standard Deviation	Variance
Low-SES students	98.66	41.32	1706.96
New immigrant children	89.49	30.84	951.31
Typical learners	107.49	44.75	2002.96
5th-graders			
Different groups	Mean scores	Standard Deviation	Variance
Low-SES students	102.59	48.19	2322.28
New immigrant children	107.32	42.08	1770.43
Typical learners	126.73	54.32	2950.35
6th-graders			
Different groups	Mean scores	Standard Deviation	Variance
Low-SES students	145.98	61.32	3759.57
New immigrant children	167.03	49.05	2405.77
Typical learners	164.70	64.01	4097.47

Table 4. Welch's Robust Tests of Equality of Means for Fourth, Fifth, and Sixth Graders

	Statistics [a]	df1	df2	Sig
4th-graders	9.387	2	153.630	.000
5th-graders	9.701	2	100.587	.000
6th-graders	3.726	2	98.014	.028

a. Asymptotically *F* distributed.

Table 5. Games-Howell's Post Hoc Comparisons by Different Group of Students in 4th, 5th, and 6th Grades

4th-graders				
Different groups		Mean Difference	Std. Error	Sig.
G1	G2	9.167	5.652	.239
	G3	-8.826	4.740	.154
G2	G1	-9.167	5.652	.239
	G3	-17.993*	4.254	.000
G3	G1	8.826	4.740	.154
	G2	17.993*	4.254	.000
5th-graders				
Different groups		Mean Difference	Std. Error	Sig.
G1	G2	-4.729	8.402	.840
	G3	-24.137*	6.498	.001
G2	G1	4.729	8.402	.840
	G3	-19.408*	6.515	.011
G3	G1	24.137*	6.498	.001
	G2	19.408*	6.515	.011
6th-graders				
Different groups		Mean Difference	Std. Error	Sig
G1	G2	-21.046	10.007	.095
	G3	-18.719*	7.106	.025
G2	G1	21.046	10.007	.095
	G3	2.328	8.405	.959
G3	G1	18.719*	7.106	.025
	G2	-2.328	8.405	.959

Note. G1 represents low-SES students, G2 represents new immigrant children, and G3 represents typical learners

to the lowest for fifth graders were typical learners, new immigrant children and low-SES students. However, as to sixth graders, the highest mean score was new immigrant children. Interestingly, the typical learners at each grade had the largest standard deviation, while the new immigrant children had the smallest standard deviation.

To examine the differences on number sense performance among the three groups of students in fourth, fifth, and sixth grade, a one-way ANOVA was performed (α = .05). Levene test of homogeneity showed the assumption of homogeneity of variance among the three groups was violated (F=6.51, p=.02, for fourth grade; F=3.46, p=.03, for fifth grade; F=3.13, p=.04, for sixth grade). Therefore, Welch-ANOVA was conducted. Table 4 summarized the results of Welch-ANOVA on number sense performance for fourth graders to sixth graders.

Data analysis showed that there were statistically significant differences among low-SES students, new immigrant children, and typical learners on number sense performance (F= 9.387, p = .000 for fourth graders; F= 9.701, p = .000 for fifth graders; F=3.726, p = .028 for sixth graders). To examine which subgroups were different on number sense performance, Games-Howell post hoc comparison was done and summarized in Table 5.

Data analysis revealed a statistically significant difference between typical learners and new immigrant children in fourth grade (mean difference = 17.993, p = .000, α = .05). For fifth graders, the results of Games-Howell showed that there were statistically significant differences between typical learners and low-SES students (mean difference = 24.137, p = .001, α = .05) and typical learners and new immigrant children (mean difference = 19.408, p = .011, α = .05). For sixth graders, the results of post hoc comparison indicated that there was a statistically significant difference on number sense performance between typical learners and

low-SES students (mean difference = 18.719, p = .025, α = .05).

In summary, in fourth grade typical learners had the highest mean score, with low-SES students having the second highest mean score and new immigrant children having the lowest mean score. For fifth graders, typical learners, new immigrant children, and low-SES students scored the highest to the lowest mean score, respectively. However, for sixth graders, new immigrant children, typical learners, low-SES students scored the highest to the lowest means score, respectively. These scores indicated that as new immigrant children entered higher grade levels, their number sense performance was improved in comparison to other student subgroups. Moreover, the results of post hoc comparisons showed that there was a statistically significant difference between typical learners and new immigrant children in fourth grade. There was a statistically significant difference between typical learners and new immigrant children and between typical learners and low-SES students in fifth grade. Finally, a statistically significant difference on number sense performance existed between typical learners and low-SES students in sixth grade.

Differences in the Methods Used by Students among Three Groups

Table 6 summarized the percentages of solution methods used by students across the three groups of fourth, fifth, and sixth graders when responding to number-sense problems. Data showed that a high percentage of students had misconceptions in each grade. Moreover, fifth and sixth graders seemed to have more serious misconceptions than fourth graders. It is important to reflect on this issue: Why did this sample of students have a large number of misconceptions after having taken an elementary school mathematics course? Data also showed that typical learners had the highest percentage of number sense-based methods and new immigrant children had the lowest percentage for fourth graders. In fifth grade, typical learners were still the highest percentage group in applying number sense-based methods. However, low-SES students had the lowest percentage in using number sense-based methods. Surprisingly, new immigrant children in sixth grade more frequently used number sense-based methods than typical learners and low-SES students.

To examine the significant differences of solution methods used by students among the three groups, the test of homogeneity of percentages was used to analyze the causalities of groups and methods. Table 7 reported theχ2-test results of methods used by different types of students in fourth, fifth, and sixth grade (α = .05). Data showed that there were significant differences in the uses of solution methods for different types of students in fourth, fifth and sixth grade (χ2=86.713, p=.000 for fourth grade; χ2=163.225, p=.000 for fifth grade; χ2 =52.804, p=.000 for sixth grade). In other words, the strategies used by the students of different backgrounds were significantly different. To examine which groups had significant differences in methods in fourth, fifth, and sixth grade, the posteriori comparisons were used.

Results of Chi-squared test showed that the

Table 6. The Percentages of Methods Used by the Three Groups of Students for 4 to 6 Graders

4th-graders				
Different groups	Number sense	Rule-based	Misconception	Guess
Low-SES students	23.97%	16.69%	38.30%	21.04%
New immigrant children	19.02%	18.07%	44.52%	18.39%
Typical learners	26.74%	17.56%	38.05%	17.65%
Average	25.48%	17.49%	38.78%	18.24%
5th-graders				
Different groups	Number sense	Rule-based	Misconception	Guess
Low-SES students	15.83%	11.44%	46.06%	26.67%
New immigrant children	17.20%	12.85%	48.30%	21.65%
Typical learners	22.12%	14.28%	45.37%	18.23%
Average	20.89%	13.79%	45.73%	19.59%
6th-graders				
Different groups	Number sense	Rule-based	Misconception	Guess
Low-SES students	20.17%	11.43%	48.09%	20.31%
New immigrant children	24.50%	11.85%	46.60%	17.05%
Typical learners	24.44%	11.92%	46.30%	17.34%
Average	23.68%	11.83%	46.64%	17.85%

Table 7. Summary of Chi-Square Tests for Homogeneity by Different Groups of Students in 4 to 6 Graders

	Pearson Chi-Square	*df*	Asymp. Sig.
4th-graders	86.713	6	.000
5th-graders	163.225	6	.000
6th-graders	52.804	6	.000

Table 8. Marascuilo Procedure for Determining Pairwise Difference on Methods Used by Different Types of Students in 4 to 6 Grades

Grade	Method	Contrasts	Abs Dif	SE of Dif	CR
4th-graders					
	Number sense	G3＞G2	.077	.009	.032
		G1＞G2	.049	.011	.041
	Misconception	G2＞G3	.065	.011	.040
		G2＞G1	.062	.014	.049
	Guess	G1＞G3	.034	.008	.029
5th-graders					
	Number sense	G3＞G2	.049	.009	.032
		G3＞G1	.063	.008	.028
	Rule-based	G3＞G1	.028	.007	.024
	Guess	G1＞G2	.050	.013	.045
		G1＞G3	.084	.009	.032
6th-graders					
	Number sense	G2＞G1	.043	.011	.040
		G3＞G1	.043	.007	.023
	Guess	G1＞G3	.030	.006	.023

Note.: G1 represents low-SES students , G2 represents new immigrant children, G3 represents typical learners , Abs Dif represents Absolute difference between different groups, SE of Dif represents Standard Error of Difference, CR represents Critical Ratio, Abs Dif > CR indicates reject H_0: No difference.

percentages of solution methods across different groups of students were different in fourth, fifth, and sixth grade. To identify which pairs of the percentages of solution methods used by the groups differed, the Marascuilo procedure for the post hoc comparison was used. Marascuilo contrasts were calculated for each pair of cells after a significant chi-square result. Table 8 reports the results of Marascuilo procedure for determining pairwise differences on the use of methods for fourth, fifth, and sixth graders.

For fourth-grade students, the percentages of number sense-based methods used by the typical learners (G3) and the low-SES students (G1) were significantly higher than the new immigrant children (G2). There were no significant differences among the three groups in applying the rule-based method. The percentages of the new immigrant children (G2) having misconception were significantly the highest among the three groups. At the same time, the low-SES students (G1) adopted significantly more guessing than the typical learners (G3).

For fifth-grade students, the percentages of number sense-based methods used by the typical learners (G3) were significantly higher than the other two groups. Then, the typical learners (G3) adopted more the rule-based methods than the low-SES students (G1). Moreover, there is no significant difference among the three groups in applying misconception. Finally, the percentages of the low-SES students (G1) adopting guessing were significantly the highest of the three groups.

For sixth-grade students, the percentages of number sense-based methods used by the typical learners (G3) and the new immigrant children (G2) were significantly higher than the low-SES students (G1). There were no significant differences among the three groups in applying the rule-based method and misconception. About guessing, the percentages of the low-SES students (G1) were significantly higher than the typical learners (G3).

DISCUSSION

This study examined the difference in number sense performance among typical learners, new immigrant children, and low-SES students from grades 4 to 6 in Taiwan through a web-based two-tier test for number sense. It provides an opportunity not only to better

understand students' number sense performance but also to explore students' thinking about number sense. Results showed that typical learners performed the best on the number sense two-tier test among the three groups when they were in the fourth and fifth grades. However, new immigrant children performed best on the number sense two-tier test among the three groups when they were in the sixth grade. This suggested that new immigrant children gradually became adept in number sense applications when they entered a higher grade level. In addition, data also showed that there were significant differences in the uses of solution methods for different types of learners in fourth, fifth and sixth grade via chi-square tests for homogeneity of proportions. In fourth grade, new immigrant children had significantly the lowest percentage of number sense-based methods used as compared to the other two groups. In fifth grade, both low-SES students and new immigrant children had significantly lower percentages in the use of number sense-based methods. In sixth grade, low-SES students adopted significantly lower number sense-based methods than the other two groups. It seemed new immigrant children slowly enhanced number sense-based methods from grade four to six. For misconception, the percentages of new immigrant children adopting misconception were significantly the lowest at grade four. However, there was no significant difference among the three groups in producing misconception at grade five and six. Overall, the new immigrant children presented a step-by-step growth in number sense. These findings were different from the earlier studies that indicated new immigrant children often encountered difficulties in adapting to a new environment, which affected their mental development (Chang, 2005; Doctoroff, 2001). In addition, this result also differed from earlier studies suggested that new immigrant children were often at a considerable disadvantage compared to their peers at school (Bohlmark, 2009; Crosnoe, 2005; Kao & Rutherford, 2007; Schnepf, 2007). Meanwhile, the study of Yao (2009) and Chen et al. (2008) showed that not all new immigrant children at earlier grade performed poor on mathematics achievement. Their studies revealed that some of new immigrant children performed well and some of them performed poor on mathematics. There are two possible reasons to explain why new immigrants may be able to improve their number sense performance while the low SES group students cannot. Firstly, due to the differences of culture and language, new immigrated students could temporarily fall behind in learning (Gee, 2004; Hsiao, 2009; Kilbride & Ali, 2010). Growing and changing with time, new immigrant children's learning performance improved because they accustomed to the present environment; therefore, it seemed the long-term economically disadvantaged situation was the key factor to have a bearing on learning effect instead of adaptable issue for language and culture. Secondly, the background of these foreign-born mothers does not affect their children's long-term learning outcomes. This confirms the earlier study of Chen (2010) that children's learning effects are not affected by their parents' background (native-born parents vs foreign-born mother and native-born father). In fact, most of these foreign-born mothers learn Chinese after they married Taiwanese. After they have learned Chinese for several years, they are able to communicate with their children (Chen, 2010). Gradually, they can help their children in learning (Chen, 2010). However, native-born mothers in low-SES families always try hard to earn a living so they barely pay attention to children's learning. Therefore, new immigrant children could make a great progress on number sense than low-SES children do.

Furthermore, results also showed that low-SES students continued to have poor performance on number sense compared to typical learners and the new immigrant children. This is similar to several earlier studies (Arnold & Doctoroff, 2003) that indicated that low-SES students had a high degree of failure in their academic achievement. It is reasonable to believe that children from poor families have more difficulties in learning mathematics compared with their school peers (Chen et al., 2008; Yao & Yang, 2010). This suggests that we should pay more attention to low-SES students' learning in mathematics classrooms (Deschenes et al., 2001; NCTM, 2000; NRC, 2001; Rodriguez, 2005). To achieve equity in mathematics learning for all students, we should provide more opportunities for low-SES students to learn number sense.

CONCLUSION

The findings indicated that there were statistically significant differences on number sense performance among new immigrant children, low-SES students, and typical learners for fourth, fifth, and sixth graders. The results of post hoc comparisons further showed that there was a statistically significant difference between typical learners and new immigrant children in the fourth grade. A statistically significant difference existed for typical learners and new immigrant children, and for typical learners and low-SES students in the fifth grade. Moreover, there were statistically significant differences between typical learners and low-SES students in the sixth grade. It was worth noting that the mean score of the new immigrant children was originally the lowest in the fourth grade. However, the low-SES students turned out to have the lowest mean scores when they moved to the sixth grade. It is reasonable to believe that new immigrant children may perform better after they have longer access to mathematics learning. Furthermore, the results showed that typical learners applied number

sense more often than other two groups of students in fourth, fifth, and sixth grade. However, there were no significant differences found among the three groups of learners in using the rule-based method for fourth and sixth graders. Only for fifth graders, typical learners used the rule-based method more often than the other two groups. As to misconception, the new immigrant children's percentage of misconception was the highest at grade four. It turned out to be no difference when comparing the percentages of misconception among the three groups at grade five and six. In addition, low-SES students used guessing most often among the three groups of students from grade four to six.

This study suggested that new immigrant children were not always in a disadvantaged situation compared to their peers at school. In addition, it implied that the number sense performance for low-SES students in grade four and fifth in Taiwan continued to be the poorest. This may seriously affect their mathematics learning and achievement in the future. Several studies showed a positive correlation between number sense and mathematics achievement (Halberda et al., 2008; Jordan, et al., 2007; Schneider et al., 2009; Yang et al., 2008). As the Jordan et al. (2007) study stated that number sense was the foundation for learning formal mathematics concepts and skills in the elementary schools, it is urgent to improve low-SES students' number sense. The findings of PISA (OECD, 2009) showed that young students in Taiwan received the highest scores on the mathematics test; however, there were high percentages of these students who were low achievers. If we want to change this situation, we should put more emphasis on teaching and learning number sense for low-SES students in the elementary schools in Taiwan.

Implications and future research

In this study, we focus on comparing the differences on number sense performance among low-SES students, new immigrant children, and typical learners in grade four, five, and six. However, it must be noted that the generalization of findings should be careful due to the sample size. Within the constraints of this limitation, we discuss the implications of our findings from three perspectives.

First, findings from this study add to the emerging body of literature on new immigrant children's performance on number sense. New immigrant children perform better than typical learners and low-SES students in grade six and perform better than low-SES students in grade five. This is different from previous studies that new immigrant children are often at a considerable disadvantage compared to their peers at school (Bohlmark, 2009; Crosnoe, 2005; Kao & Rutherford, 2007; Schnepf, 2007). It also supports the finding of Yao (2009) and Chen et al. (2008) that not all new immigrant children perform poor on mathematics than their peers at school.

Second, the reported findings show the need to improve the low-SES students' number sense in grade four, five, and six. This finding is consistent with the study of PISA (OECD, 2009) that there are high percentages of students in Taiwan belonging to low achievers. For low-SES students, it seems some existing factors are harder to overcome than new immigrant children. To improve this situation, providing more learning opportunities and effective learning program for low-SES students is necessary.

Third, the findings of the current study indicate that research studies focusing on low-SES students' number sense learning are needed. The teacher development centers at every university in Taiwan should offer some courses designed for training in-service teachers knowing how to help their children develop number sense effectively.

Finally, it is a worldwide issue that economically disadvantaged situation would be a factor to influence students' learning. This study found out that low-SES students remain their low learning performance mainly because of their family background which cannot provide assistance for children's learning. Therefore, if we want to improve the problem, the schools should offer more learning supports, such as remedial teaching, a subsidiary course, as well as strengthening teachers' professional knowledge.

Further research is needed to examine questions such as: (a) How can we provide more learning opportunities to improve low-SES students' number sense? (b) What kind of teaching method is more effective to promote low-SES students' number sense? (c) What kinds of instructional materials are appropriate and effective to improve low-SES students' number sense?

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REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement, 45*(1), 131-142.

Arnold, D. H., & Doctoroff, G. L. (2003). The early education of socioeconomically disadvantaged children. *Annual Review of Psychology, 54*(1), 517-545.

Atweh, B., Vale, C., & Walshaw, M. (2012). Equity, diversity, social justice, and ethics in mathematics education. In B. Perry, T. Lowrie, T. Logan, A. MacDonald, & J. Greenlees (Eds.), *Research in Mathematics Education in Australia 2008-2011* (pp. 39-66). Rotterdam: Sense Publishers.

Berch, D. B. (2005). Making sense of number sense: Implications for children with mathematical disabilities. *Journal of Learning Disabilities, 38*(4), 333-339.

Birman, D., Weinstein, T., Beehler, S., & Chan, W. (2007). Immigrant youth in U.S. schools: Opportunities for prevention. *The Prevention Researcher, 14*(4), 14-17.

Bohlmark, A. (2009). Integration of childhood immigrants in the short and long run-Swedish evidence. *International Migration Review, 43*(2), 387–409.

Carboni, L. (2008). *Number sense everyday*. The University of North Carolina at Chapel Hill. Retrieved from http://www.learnnc.org/lp/pages/numsense0402-1.

Chang, M. H. (2005). Development and multiculturalism: The development of new Taiwanese children and new immigrant women. In *Do not call me "foreign bride"*, ed. H. C. Hsia, 206-215. Taipei County, Taiwan: Rive Gauche Publishing House. (In Chinese).

Chen, J. J. (2010). The effect of intermarriage on child's learning achievement. *Educational Research Journal, 21*(2); 61-89. *(in Chinese)*.

Chen, S. H., Yang, D. C., Yao, R. F., & Lai, M. L. (2008, November). *A cultural study of disadvantaged lower grade students' mathematical learning*. Paper presented at the Conference Series on Education Development in Chinese Society- Curriculum and Instruction, Macau University, China.

Cramer, K. A., Post, T. R. & delMas, R. C. (2002). Initial fraction learning by fourth- and fifth-grade students: A comparison for the effects of using commercial curricula with the effects of using the rational number project curriculum. *Journal for Research in Mathematics Education, 33*(2), 111-144.

Crosnoe, R. (2005). Double disadvantage or signs of resilience? The elementary school contexts of children from Mexican immigrant families. *American Educational Research Journal, 42*(2), 269-303.

Deschenes, S., Cuban, L., & Tyack, D. (2001). Mismatch: Historical perspectives on schools and students who don't fit them. *Teachers College Record, 103*(4), 825-547.

Doctoroff, S. (2001). Adapting the physical environment to meet the needs of all young children for play. *Early Childhood Education Journal, 29*(2), 105-109.

Dunphy, E. (2007). The primary mathematics curriculum: Enhancing its potential for developing young children's number sense in the early years at school. *Irish Educational Studies, 26*(1), 5-25.

Durbin, J., & Watson, G. S. (1971). Testing for serial correlation in least-squares regression III. *Biometrika, 58*(1), 1–19.

Dyson, N. I., Jordan, N. C., & Glutting, J. (2013). A number sense intervention for low-income kindergartners at risk for mathematics difficulties. *Journal of Learning Disabilities, 46*(2), 166-181.

Empson, S. B. (2003). Low-performing students and teaching fractions for understanding: An interactional analysis. *Journal for Research in Mathematics Education, 34*(4), 305-343.

Geary, D. C., Bow-Thomas, C. C., & Yao, Y. (1992). Counting knowledge and skill in cognitive addition: A comparison of normal and mathematically disabled children. *Journal of Experimental Child Psychology, 54*(3), 372-391.

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling*. New York: Routledge.

Griffin, S., Case, R., & Siegler, R. (1994). Rightstart: Providing the central conceptual prerequisites for first formal learning of arithmetic to students at risk for school failure. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 24–49). Cambridge, MA: MIT Press.

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and intervention for students with mathematics difficulties. *Journal of Learning Disabilities, 38*(4), 293-304.

Halberda, J., Mazzocco, M., & Feigenson, L. (2008). Individual differences in nonverbal number acuity predict math achievement. *Nature, 455,* 665-668.

Hsiao, Y. J. (2009). A study of childrearing, school methods, and government policies that affect preschool children of immigrant mothers in Southern Taiwan. PhD diss., Spalding University, Louisville, KY, USA.

Hsin, C. T. (2010, May). *Funds of knowledge relative to young children's literacy learning in new immigrant families in Taiwan.* Paper presented at the American Educational Research Association (AERA) Annual Meeting, Denver, CO, USA.

Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences, 20*(2), 82-88.

Jordan, N. C., Kaplan, D., Oláh, L. N., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77*(1), 153-175.

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade mathematics achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice, 22*(1), 36-46.

Jordan, N. C., Raminent, C., & Watkin, M. W. (2010). Validating a number sense screening tool for use in kindergarten and first grade: Prediction of mathematics proficiency in third grade, *School Psychology Review, 39*(2), 181-195.

Kao, G., & Rutherford. L. T. (2007). Does social capital still matter? Immigrant minority disadvantage in school-specific social capital and its effects on academic achievement. *Sociological Perspectives, 50*(1), 27–52.

Kern, D. E. (2012). *CliffsNotes praxis II: principles of learning and teaching (second edition)*. USA: John Wiley & Sons, Incorporated.

Kilbride, K. M., & Ali, M. A. (2010). Striving for voice: Language acquisition and Canadian immigrant women. *Current Issues in Language Planning, 11*(2), 173-189.

Khan, A., & Rayner, G. D. (2003). Robustness to non-normality of common tests for the many sample location problem. *Journal of Applied Mathematics and Decision Sciences*, *7*(4), 187-206.

Kaminski, E. (2002). Promoting mathematical understanding: Number sense in action. *Mathematics Education Research Journal, 14*(2), 133-149.

Mazzocco, M. M. M., & Thompson, R. E. (2005). Kindergarten predictors of math learning disability. *Learning Disabilities Research and Practice, 20*(3), 142-155.

McIntosh, A., Reys, B. J., & Reys, R. E. (1992). A proposed framework for examining basic number sense. *For the Learning of Mathematics, 12*(3), 2-8.

Mendoza, M. (2002). *Latino immigrant women in Memphis.* Memphis, TN: Center for Research on Women, University of Memphis. (ERIC Document Reproduction Service No. ED 472386)

Miller, J. (2009). *Hispanic immigrant students.* PhD diss., Texas Women's University, Denton, TX, USA.

Ministry of Education in Taiwan. (2010). *Twelve-year joint mathematics curricula plan in Taiwan.* Taiwan: Taipei. (In Chinese).

Ministry of Interior Taiwan. (2010). The baby was born and count dividing according to breeder mother's nationality in recent years in Taiwan. Taipei, Taiwan: Ministry of Interior. (In Chinese).

Mo, L. L., & Lai, P. Z. (2004). To explore the decreasing birth rate and foreign spouses' children in Taiwan. *Journal of Community Development, 105*, 55-65. (In Chinese).

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2009). Risk factors for learning-related behavior problems at 24 months of age: Population-based estimates. *Journal of Abnormal Child Psychology, 37*(3), 401-413.

Nasir, N. S., & Cobb, P. (Eds.) (2007). *Improving access to mathematics: Diversity and equity in the classroom.* New York: Teachers College Press.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics*. Reston, VA: NCTM.

National Research Council. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations.* Washington, DC: National Academy Press

Organization for Economic Co-operation and Development. (2009). *Programme for international student assessment (PISA).* Retrieved from http://pisa2006.acer.edu.au.

Oakes, J., Joseph, R., & Muir, K. (2004). Access and achievement in mathematics and science: inequalities that endure and change. In *Handbook of research on multicultural education* ed. J. A. Banks & C. A. McGee Banks (pp. 69-90). San Francisco: Jossey Bass.

Pogrow, S. (2009). Accelerate the learning of 4th and 5th graders born into poverty. *Phi Delta Kappan, 90*(6), 408-412.

Peng, P. C. (2007). *New immigrant children's complicated becomings: A multi-sited ethnography in a Taiwanese diasporic space.* Unpublished doctoral dissertation, Ohio State University. Retrieved from http://www.ohiolink.edu/etd/sendpdf.cgi/Peng%20Pingchuan.pdf?acc_num=osu1181924608

Reys, R. E. & Yang, D. C. (1998). Relationship between computational performance and number sense among sixth- and eighth-grade students in Taiwan, *Journal for Research in Mathematics Education, 29(2),* 225-237.

Rodriguez, A. J. (2005). Teachers' resistance to ideological change: Definitions, theoretical framework, and significance. In *Preparing mathematics and science teachers for diverse classrooms*,ed. A. J. Rodriguez & R. S. Kitchen (pp. 1-16). Mahwah, NJ: Lawrence Erlbaum Associates.

Schneider, M., Grabner, R. H., & Paetsch, J. (2009). Mental number line, number line estimation, and mathematical achievement: Their interrelations in grades 5 and 6. *Journal of Educational Psychology, 101*(2), 359-372.

Schnepf, S. V. (2007). Immigrants' educational disadvantage: An examination across ten countries and three surveys. *Journal of Population Economics, 20*(3), 527-545.

Seah, W. T., Atweh, B., Clarkson, P., & Ellerton, N. (2008). Sociocultural perspectives in mathematics teaching and learning. In H. Forgase, A. Barkatsas, A. Bishop, B. Clarke, S. Keast, W. T. Seah & P. Sullivan (Eds.), *Research in Mathematics Education in Australia 2004-2007* (pp. 223-254). Rotterdam: Sense Publishers.

Sood, S., & Jitendra, A. K. (2007). A comparative analysis of number sense instruction in reform- based and traditional mathematics textbooks. *Journal of Special Education, 41*(3), 145-157.

Sreeharsha, K. (2010). *Reforming Americ's immigration laws: A woman's struggle.* Washington, DC: Immigration Policy Center.

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly, 19*(1), 99-120.

Tan, Y. C., & Wu, C. S. (2009). The study on the policy for low-SES students and its coping measures in Taipei city. *Journal of Educational Administration and Evaluation, 8(1),* 77-94. (In Chinese).

Verschaffel, L., Greer, B., & De Corte, E. (2007). Whole number concepts and operations. In F. K. Lester, Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 557-628). Charlotte, NC: Information Age Publishing.

Wang, W., Young, S., & Smith, J. (2009). Experiences of learning to read in New Zealand: A case study of five Chinese families. *New Zealand Journal of Education Studies, 44*(2), 31-46.

Wright, R. J., Stanger, C., Cowper, M., & Dyson, R. (1996). First graders' progress in an experimental mathematics recovery program. In Children's number learning: A research monograph of MERGA/AAMT (pp. 55–72). Adelaide, Australia: Australian Association of Mathematics Teachers.

Yang, D. C. (2010). The design and application of web-based two-tier test for number sense, paper presented at the 8th Annual Hawaii International Conference on Education. Hawaii, U. S. A. Jan7-10, 2010.

Yang, D. C. & Li, M. N (2013). Assessment of Animated Self-Directed Learning Activities Modules for Children's Number Sense Development. *Journal of Educational Technology and Society, 16*(3), 44-58.

Yang, D. C., Li, M. N., & Lin, C. I. (2008). A Study of the Performance of 5th Graders in Number Sense and its Relationship to Achievement in Mathematics, *International Journal of Science and Mathematics Education, 6(4),* 789-807.

Yang, D. C. & Wu, W. R. (2010). The study of number sense realistic activities integrated into third-grade math classes in Taiwan. *The Journal of Educational Research*, *103(6)*, 379-392.

Yao, R. F. (2009, July). *Investigation on mathematics learning of the "new children of Taiwan"*. Paper presented at the 33rd Conference of the International Group for the Psychology of Mathematics Education, Thessaloniki, Greece.

Yao, R. F., & Yang, D. C. (2010, December). *Creating appropriate mathematics learning environments for low-SES students through remedial instructional modules*. Paper presented at the second annual Asian Conference on Education (ACE 2010), Osaka, Japan.

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Appendix: One item for the web-based two-tier test showed as following Step 1 & Step 2

Step 1: Student chooses an answer.

Question 23 ／ total questions of the test is 25		
Question	The Taiwan 101 skyscraper has 101 floors. Which of the following has a height that is approximately the height of the skyscraper?	
Answer:	○	2.4km-high Mountain
	○	A 90m-high sacred tree
	○	A 450m-high Waterfall
	○	The total height of 101 people stacking together
Submit		

Step 2: According to the answer, the student is required to choose a reason for the selection.

My reason is	
○	A 101-story building is very tall, so 2.4 km will most likely be close to the height of the building.
○	The unit of km is the most appropriate for a tall building of 100 floors.
○	I'm guessing.
Submit	

My reason is	
○	A 101- story building is approximately the same height as a sacred tree.
○	All of the other heights provided are impossible because they are too large.
○	I'm guessing.
Submit	

My reason is	
○	450m is the middle value of all the heights provided, which makes it more probable.
○	One floor is approximately 4m in height, so a 101-floored building will make a height of about 450m.
○	I'm guessing.
Submit	

My reason is	
○	The height of one floor is approximately the height of a person.
○	The height of the skyscraper is about the height of 101 people stacked together.
○	I'm guessing.
Submit	