

The European Journal of Social and Behavioural Sciences
EJSBS Volume XXV, Issue II (e-ISSN: 2301-2218)

FROM NONSENSE TO NUMBER SENSE: ENUMERATION OF NUMBERS IN MATH CLASSROOM LEARNING

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Abstract

The overall goal of learning mathematics is to induce a lifelong understanding that allows students to adapt to contemporary changes and demands. Advances in our society cause an abundance of data bombarding us on a daily basis. As a result, mathematics skills must extend beyond the ability to enumerate or sense making. Thus, this study was conducted with the aim of assessing 215 randomly selected students aged 14 to 16 in their enumeration of numbers. The moderating variables for this study include grade level (Secondary 2 and Secondary 4) and gender. This study was based on a purely quantitative approach using a paper and pencil test to assess these students' number sense. The findings show both Secondary 2 students and Secondary 4 students obtained a low-level mean score of 22.59 (SD=9.64) and 24.85 (SD=7.76) from a maximum score of 50. These findings show no statistical significant differences at the 0.05 level. The findings also depicted that male students obtained a higher mean score across secondary 2 and secondary 4, though the former were not statistically significant. The findings also showed that the influences between number sense and school mathematics results are correlative. Learners must be able to interpret, evaluate, recognize patterns, make comparisons, and understand relationships from data. This data in number forms must make sense to students before any meanings can be attached to it. Number sense, as it is known, is based on the fundamental of understanding what numbers mean, how the numbers are represented, how the numbers are correlated to one another and how the computations of those numbers take place. This supports the notion that when students are good in number sense, it will increase and enhance their usage of mathematics in everyday life.

Keywords: Number sense, school math, learning, enumeration

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doi: 10.15405/ejsbs.256



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1. Introduction

The overall goal of learning mathematics is to induce a lifelong understanding that allows them to adapt to contemporary changes and demands. Students must be equipped with the mathematical skills that make them relevant and productively functional in the ever-changing technological world by granting them versatility, fluidity and creativity. Advances in our society has caused an abundance of data bombarding us on a daily basis. As a result, mathematics skills must extend beyond the ability to calculate, enumerate and sense making. Learners must be able to construe, appraise, identify patterns, make contrasts, and comprehend relationships from data. This data in number forms must make sense to students before any meanings can be attached to it. Ultimately, number sense relies on the fundamental of understanding what numbers mean, how the numbers are represented, how the numbers are correlated to one another and how the computations of those numbers take place.

Enumeration of numbers is the ability of making sense of numbers. At times, this term is used interchangeably with number sense where it refers to the process of making sense of numbers and its relationship to the operation with the ability to fluidly use such comprehension to make judgments or solve a mathematical problem (Yang, 2003). Yang further explicates enumeration as the individuals' comprehension of the nature and process of numbers along with the capability to create valuable, versatile and effective strategies for handling numerical problems. In other words, number sense refers to the students' insight or intuition with numbers concepts that includes a sense in their ability to solve a numerical problem in a significant manner (Singh, 2009).

Given the context, nurturing students' capacity to understand numbers, how they are represented, how they are related to each other and how all these factors Secondary the number system should become focus areas for our education system and it must be inculcated in the teaching and learning of mathematics (Nickerson & Whitacre, 2010; McIntosh, Reys, & Reys, 1992). If students are expected to make sense how numbers are authentically used in their daily lives, they will need to first understand the nature of the numbers. As such, they will need to quantify; locate, specifically, a particular object in a collective; as well as name and measure with numbers. As they progress into working with computations and numbers at a higher level, the understanding of place value would also become salient. Along with this, there have been numerous suggestions by mathematics educators that the processes of mathematics learning and mathematics instructions should focus on the students' understanding of numbers and its operations (Singh & Sian Hoon, 2011; Ghazali, 2001; Noor Azlan & Munirah, 1999)

before it can be used meaningfully for further induce enhancement in mathematics learning progression.

As Ekenstam (1977) stated 40 years ago, "The lack of understanding of what numerals mean must present insuperable barriers to learning mathematics" (p. 317). The important realization is that the core of number sense includes developing knowledge on the correlation between multiple mathematical concepts, skills, and facts which in return would grant the person various and seamless access to these concepts when required in life. He posited that an individual who could not comprehend that US1.20 would be displayed as 1.2 on the calculator; or have the awareness that $15/17$ is lesser than 1; and 2000 is actually one hundred 20's – would have to memorize a plethora of mathematical rules and laws just to go through daily numerical situations. This was also similarly posited by Singh, and Sian Hoon (2017):

Unfortunately, the development of mathematical thinking in their learning is overshadowed by an instructional focus on decontextualized content and the imparting of facts necessary to pass end of semester examinations. They end up with islands of superficial knowledge without a canoe to get from one end to the other. (p. 141)

Hence, the question to ponder is if this scenario is prevalent among secondary school students in Malaysia.

2. Background and Problem Statement

Findings from previous researches show that number sense abilities among school students are still weak. The findings over the decades have shown that students are still struggling to grasp the concept of number sense (Noor Azlan & Munirah, 1999; Mohamed & Johnny, 2010; Singh & Sian Hoon, 2011). Noor Azlan and Munirah (1999) in their study found that students face little difficulties in engaging procedural algorithms, but are largely incompetent in mastering the comprehension of operations and numbers; number sizes and their relativity; composing numbers; and significantly realizing the effects of operations on numbers. Similarly, Mohamed and Johnny (2010) found the students rarely face problems with using memorized formulae in solving a given task. On the contrary, they perform generally poorly when their competency in number sense is tested. Similarly, in a study by Singh and Sian Hoon (2011) among 1756 students, ages ranging from 12 to 17 years, they elucidated that there is an increasingly worrying overreliance on algorithm and procedures as the school years increase. They further opined that intuitive number comprehension has been greatly eroded by students' overreliance on paper and pencil computation.

This doesn't necessarily mean that Malaysian educators are completely oblivious to the problem. Over the past 5 years, various reforms have been taken by the Malaysian Ministry of

Education (MOE) to enhance our education system due to its low performance in International studies such as TIMSS and PISA. Among the reforms include Standard Based Curriculum for Secondary Schools (KSSM) and Standard Based Curriculum for Primary Schools (KSSR) that were introduced in 2016. This initiative was documented in the Malaysian Education Blueprint 2013-2025. According to the former education minister Datuk Seri Mahdzir Khalid, items like creative thinking, problem-solving, innovation and leadership have been introduced into the primary and secondary curriculum to instill a balanced and holistic education process (“Malay Mail”, 2016). He further elucidated that “The curriculum emphasises on the teaching that centres on the students and focuses more on problem-solving, project-based assignments, updating subject or theme and implementing formative assessments”. Since this reform took place about 2 years ago, one should ponder whether there has been any improvement in the teaching and learning of mathematics in schools, especially in the context of making meaning sense of their learning.

This current KSSM curriculum very much relates to the integration of thinking and numbers in mathematics teaching and learning. This composite, multi-layered and arbitrary nature of integration suggests that it cannot be confined to specific books or chapters. Rather, the development of thinking complexities and the ability to make sense of numbers stem from a comprehensive range of activities that permeates the entirety of mathematical education and teaching (Greeno, 1991). The reformative movement has promoted a shift in the central goal of school mathematics: from the memorization of algorithms to conceptual understanding which include numbers. At the crux of such formation are function and number senses that are seen as the most fundamental requirements to such understanding (Picciotto, 1998). Researchers believe that as an individual moves into a secondary school, number sense becomes more and more essential, but are Malaysian secondary school students aptly equipped with number sense to be able to digest the visionary content drawn up in the KSSM?

The stark truth here is that, it is high time to find out everything about number sense, from how it changes children through adulthood to the impact of number sense perception. It is important to track students over several years in order to understand how these students develop number systems during their exposure to the mathematics curriculum (Halberda & Feigenson, 2008). Mohamed and Johnny (2010) claimed that focusing on certain elements in number sense can elucidate the difficulties faced by students in solving problems.

3. Purpose and Significance of the Study

The questions to ponder at the current time are: What is the current level of secondary school students’ conceptions of number sense? Have there been any changes in their

development of number sense since the introduction of KSSM and the introduction of HOTS (higher order thinking skills) in the learning of mathematics? This study aims to identify the level of students' performance in number sense after undergoing the revamped primary and secondary mathematics curriculum to uncover the efficacy of the curriculum.

The findings of this study would be significant for the stakeholders (such as teachers, researchers, curriculum developers) to reconsider the mathematics instructions that is taking place in school and its impact on students' conceptualization of numbers. The teachers will be able to evaluate their teaching methodologies in its relationship to students' enumeration of numbers. Thus, the teaching processes can be upgraded, where necessary, to help students develop meaningful learning of mathematics in the context of enhancing student's prowess in numbers. Secondly, the curriculum developers will be able to evaluate if the KSSM curriculum currently being used in schools has actually enhanced students' development of number sense. Thirdly, researchers in the area of mathematics education will be able to forge future directions of research into the teaching of number sense, hence enhancing number sense curriculum development.

4. Research Objectives

The objectives of this study are to:

- 4.1 Assess the level of students' achievement in the Number Sense Test across grade levels and gender.
- 4.2 Examine the relationship between number sense achievement with i) grade levels and ii) gender

5. Methodology

A quantitative approach using a descriptive design was utilised through the administration of a paper and pencil test in order to provide a picture of students' sense of numbers.

A total of 215 samples randomly selected using a stratified sampling technique from the five schools (refer to table 1) were involved in the study. The total population of Secondary 2 and Secondary 4 students from the district involved was approximately 7000 students based on the data provided from the state education department. Using the Krejcie and Morgan (1970) table, the sample size requirement was determined to be approximately 217. Thus, the sample size for the study adhered to the sample size requirement needed to be representative of a given population. The composition of the samples is shown in Table 1.

Table 1. Demographics of participants by grade level and gender

Gender	Secondary 2	Secondary 4	Total
Male	50	65	115 (53.5%)
Female	44	56	100 (46.5%)
Total	94	121	215 (100.0%)
	43.7%	56.3%	

The compositions of the samples as shown in table 3.1 comprise 43.7% (n=94) Secondary 2 students and 56.3% (n=121) Secondary 4 students. From this total, 53.5% (n=115) were male students compared to 46.5% (n=100) as female students.

The instrument used in this study to assess students' development of number sense was adapted from McIntosh, Reys & Reys (1992). There were 50 items in the Number Sense Test (NST). Both levels (Secondary 2 and Secondary 4) used the same test items for the assessment purpose. The scoring rubric for the NST was adopted based on the criteria used by McIntosh et al. (1992). Hence, a scoring rule was determined as follows:

1. If the answer was correct, 1 point was given,
2. If the answer was incorrect or no response, 0 point was given.

Thus, the total score for the NST was 50.

6. Findings

This section details the findings of study based on the research questions posed.

6.1. Research Question 1

6.1.1. What is the level of students' achievement in the NST?

6.1.2. Is there a significant difference in the means scores of the NST between grade levels?

H₀: There is no significant difference in the mean scores between the Secondary Two students and the Secondary Four Students in the NST.

H₁: Secondary Four students obtained a higher mean score than the Secondary Two students in the NST.

Table 2 shows the mean scores obtained by both the Secondary 2 and Secondary 4 students in the NST. The data shows the scores obtained by the Secondary 2 students is 22.59 (SD=9.64) as compared to 24.85 (SD=7.76) by the Secondary 4 students out of the maximum score of 50. In terms of percentage score, the Secondary 4 students obtained an average of

49.7% as compared their Secondary 2 counterparts with an average of 45.2%. These findings indicate students involved in the study obtained a low-level attainment in the NST.

Table 2. Descriptive statistics for then NST by grade levels

Level	N	Mean	SD	Percentage correct	t	df	Sig
Secondary 2	94	22.59	9.64	45.2%	-1.91	213	.058
Secondary 4	121	24.85	7.76	49.7%			

Max score :50

To investigate if there is a significant difference in these scores, an independent samples t-test was conducted. The analyses show that there is no significant difference in the mean scores ($t = -1.909$, $df = 213$, $p > 0.05$) between the Secondary 2 students and Secondary 4 students at the 0.05 level. Thus, we fail to reject the null hypothesis. This indicates that although Secondary Four students may be more cognitively matured based on their grade levels, this maturity did not extend to their enumeration of numbers.

6.2. Research Question 2

6.2.1. *Is there a significant relationship between Secondary 2 students' scores in the NST with their Year-end school examination scores?*

H₀: There is no significant relationship between Secondary 2 students' scores in the NST with their Year-end school examination scores.

H₁: There is a significant relationship between Secondary 2 students' scores in the NST with their Year-end school examination scores.

Table 3. Relationship between Secondary 2 students' scores in the NST with their Year-end school examination scores

		Secondary 2 Students' Year End Test	Marks for Number Sense Test (NST)
Secondary 2 Students' Year End Test	Pearson Correlation	1	.552**
	Sig. (2-tailed)		.000
	N	94	94
Number Sense Test	Pearson Correlation	.552**	1
	Sig. (2-tailed)	.000	
	N	94	94

** . Correlation is significant at the 0.01 level (2-tailed).

Table 3 shows the relationship between Secondary 2 students' scores in the NST with their Year-end school examination scores. The analyses indicate a moderately high ($r=.552$)

and significant relationship ($p < .01$) between Number Sense Test (NST) and their Mathematics Year End Test at the 0.01 level. Thus, we reject the null hypothesis. In other words, this indicates that 30.5% ($r^2 = 0.305$) of Secondary 2 students' scores in the NST can be explained by their Year-end school mathematics examination scores.

6.2.2. Is there a significant relationship between Secondary 4 students' scores in the NST with their Year-end school examination scores?

H₀: There is no significant relationship between Secondary 4 students' scores in the NST with their Year-end school examination scores.

H₁: There is a significant relationship between Secondary 4 students' scores in the NST with their Year-end school examination scores.

Table 4. Relationship between Secondary 4 students' scores in the NST with their Year-end school examination scores

		Secondary 4 Students' Year End Test	Marks for Number Sense Test (NST)
Secondary 4 Students' Year End Test	Pearson Correlation	1	.422**
	Sig. (2-tailed)		.000
	N	121	121
Number Sense Test	Pearson Correlation	.422**	1
	Sig. (2-tailed)	.000	
	N	121	121

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4 shows the relationship between Secondary 4 students' scores in the NST with their Year-end school mathematics examination scores. The analysis shows there is a moderate positive ($r = .422$) and significant correlation ($p < .01$) between Number Sense Test (NST) and Year-end school examination scores among the Secondary 4 students at the 0.01 level. Thus, the null hypothesis is rejected. This shows that approximately 17.8% ($r^2 = 0.178$) of Secondary 4 students score in NST can be explained by Year-end school examination scores and vice versa.

6.3. Research Question 3

6.3.1. Is there a significant difference in the means scores of the NST between genders?

H₀: There is no significant difference in the means scores of the NST between genders.

H₁: There is a significant difference in the means scores of the NST between genders.

The analysis of the scores obtained in the Number Sense Test (NST) between genders across the levels of Secondary 2 and Secondary 4 is shown in Table 5.

Table 5. Descriptive Statistics and Independent Samples T-Test for NST by Gender

Gender	N	Mean	Std. Deviation	t	Df	Sig. (2-tailed)
Male	115	26.36	8.61	4.74	213	.000
Female	100	20.99	7.88			

The data shows the mean scores obtained by the male students and female students are 26.39 (SD=8.61) and 20.99 (SD=7.88) respectively. To determine if there are significant differences in these scores, an independent sample t-test was conducted. The analyses as shown in Table 5 shows a significant difference in the mean scores ($t(213) = 4.74, p < .05$) between male students and female students at the 0.05 level. Thus, the null hypothesis is rejected. This depicts that the male students have a higher sense of number enumeration compared to their female counterparts.

6.3.2. Is there a significant difference in the means scores of the NST between gender among the Secondary 2 students?

H₀: There is no significant difference in the means scores of the NST between genders among the Secondary 2 students.

H₁: There is a significant difference in the means scores of the NST between genders among the Secondary 2 students.

The analysis of the scores obtained in the NST between genders among the Secondary 2 students is shown in Table 6.

Table 6. Descriptive statistics and Independent Samples T-Test for NST by Gender among Secondary 2 students

Gender	N	Mean	Std. Deviation	t	Df	Sig. (2-tailed)
Male	50	23.26	8.97	.72	92	.472
Female	44	21.82	10.40			

The data shows the mean scores obtain by the male students and female students are 23.26 (SD=8.97) and 21.82 (SD=10.40) respectively. To determine if there are significant differences in these scores, an independent sample t-test was conducted. The analyses as shown in Table 4.10 shows that although male students obtained a higher mean score, these

differences were not statistically significant ($t(92) = .72, p > .05$) at the 0.05 level. Thus, we fail to reject the null hypothesis.

6.3.3. Is there a significant difference in the means scores of the NST between gender among the Secondary 4 students?

H₀: There is no significant difference in the means scores of the NST between gender among the Secondary 4 students.

H₁: There is a significant difference in the means scores of the NST between gender among the Secondary 4 students.

The analysis of the scores obtained in the NST between genders among the Secondary 4 students is shown in Table 7.

Table 7. Descriptive statistics and Independent Samples T-Test for NST by Gender among Secondary 4 students

Gender	N	Mean	Std. Deviation	t	Df	Sig. (2-tailed)
Male	65	28.74	7.57	7.03	119	.000
Female	56	20.34	5.12			

The data shows the mean scores obtained by the male students and female students are 28.74 (SD=7.57) and 20.34 (SD=5.12) respectively. To determine if there are significant differences in these scores, an independent sample t-test was conducted. The analyses as shown in table 7 show there is a significant difference in the mean scores ($t(119) = 7.03, p < .05$) among the Secondary 4 level between male students and female students at the 0.05 level. Thus, the null hypothesis is rejected. This shows that among the Secondary 4 students, the male students obtained a higher mean score in the number sense test as compared to the female students

7. Discussion of Findings

The aim of this study was to investigate students' attainment in number sense among grade levels (Secondary 2 and Secondary 4) and gender. The findings of this study show a low-level sense of number sense among the students involved in the study. The average percentage of correct responses for the scores obtained in the Number Sense Test was less than 50% across Secondary 2 and Secondary 4 students which were 45.2% and 49.7% respectively. This is supported by Singh (2009) in his study conducted 9 years ago which showed that students had obtained low scores in number sense test ranging from 37.3% to 47.7% across the levels in Malaysia. Mohamed and Johnny (2010) also highlighted that many previous

studies, both local and international, have revealed that students have poor understanding in making sense of numbers. For example, Akkaya (2016) reported that the number sense achievement of secondary school students in Turkey was also very low for each grade level. These findings reveal that students' low level sense of numbers is also prevalent in other countries. In short, this shows that the number sense development is still unsatisfactory among students in Malaysia and this is not a local but a global problem.

The findings of this study also found no significant difference in the achievement level in number sense between grade levels (Secondary 2 students and Secondary 4 students). Similar findings were reported by Singh (2009) where no significant differences were found between lower grades (Secondary 1 and 2) and upper grades' (Secondary 3 and 4) ability in number sense. Similarly, a study by Singh and Sian Hoon (2011) also reported no significant difference in the mean scores among secondary school students of different grades in a number sense test. This is contrary to the nature of human development where knowledge and maturity usually increase with the number of years in schools or, in other words, the increase in age. However, this was not the case in this investigation. This is not surprising, because according to Reys et al. (1999), the mathematics curriculum is heavily weighted on computational algorithms and procedures, thus creating an imbalance in the development of number sense and computational skills with the latter being more developed to the detriment of the former. Even Yang, Hsu, and Huang (2004) affirmed in their studies that the teaching environment that focuses primarily on mastery of written computation gives little to no help to students in developing meaningful comprehension of numbers.

In terms of gender differences, the findings show a significant difference in the mean scores between male students and female students in the Number Sense Test among the Secondary 4 students as compared to the Secondary 2 students. To be noted that, although there were no significant differences among the latter, the male students obtained a higher mean score compared to their female counterparts. The results of this study are consistent with the previous study done by Singh, Abdul Halim, and Abdul Ghani (2005) which reported male students obtaining higher scores than female students. Similarly, Chattopadhyay, Sarkar, and Koner (2017) also reported male students outperforming their female counterparts in making sense of numbers through a paper and pencil test. Akkaya (2016) in another study reported that although no significant differences between genders were found, the performance of male students was higher than female students across grades. Similarly, Şengül and Gülbağcı (2012) also reported that although no statistical difference in number sense scores between the genders were found, male students obtained higher scores than female students. The differences of performance between genders may be due to males being more exposed to out-of-family

interaction whilst the females are protected from it (Chattopadhyay et al., 2017). From these previous studies, the researchers believe that male students seem to do better in number sense because of spatial ability since heavy visualization and spatial ability are required in number sense (Battista, 1990; Walden & Walkerdine, 1982). In addition, Walden and Walkerdine (1982) also reported that males perform better at mathematics when spatial ability is needed while females had a higher success rate with algebra. According to Linn and Petersen (1985) spatial ability is known as the “skill in representing, transforming, generating and recalling symbolic, non-linguistic information” (p. 1482). However, there is a well-researched agreement that spatial abilities are found to be different in nature and level in different genders (Halpern & Collaer, 2005). In fact, to many researchers, it is one of the most consistent and reliable phenomenon of all cognitive gender differences (Halpern, 2011, as cited in Reilly, Neumann, & Andrews, 2017). In many instances, males have been found to be more proficient than females in the tests that measure visual-spatial ability, despite the widely accepted notion of variable individuality in each gender.

8. Conclusion

In this study, approximately 57% of the total samples scored above average in their mathematics end-of-the-year examination. Interestingly, the findings point to a significant gap between students’ mathematics subject grade and number sense test score, where students sense of numbers is very much lacking across all levels. One plausible explanation is the possible lack of mathematical instruction that involve number sense in schools, which results in students’ inability or near inability to apply number sense to mathematical concepts. In other words, this elucidates a worrying disparity between intuitive understanding and the capability to perform paper and pencil calculations. On top of that, many researchers (Mohamed & Johnny, 2010; Singh & Sian Hoon, 2011; Singh, 2009) have agreed that because Malaysian students are already exceptionally good in computational skills, the comprehension of the procedures would significantly allow them to be highly confident and competent in number sense if they are given a modest amount of practice. Nevertheless, should students mechanically memorize mathematical procedures without being aware of its process and nature, their conceptual understanding would fossilize and it would be very difficult to include intuitive understanding afterwards. (Resnick & Omanson 1987, as cited in Singh, 2009). Another risk of mechanical memorization of mathematical concepts is the higher chance of confusion with the methods or having forgotten the steps to the computations (Kamii &

Dominick 1998, as cited in Singh, 2009) and most poignantly, we believe such is the case with students who became the sample of this study.

Furthermore, male students performed much better than female students at both levels. As such, it is feasible to encourage more effort to expose female students to cognitive skills development specifically that involving spatial ability. The last conclusion posits that good achievements in Mathematics do not reciprocate towards understanding numbers and its operation and it does not indicate students' ability to know when and how to use the understanding in flexible ways to solve numerical problems.

Teachers need to realize that providing the best learning environment for students is one of the most essential parts of the teaching and learning process. They must remind themselves not to emphasize only the rule-based questions but make sure students understand the meaning behind it. In order to do this, teachers must have a clear understanding of the students' current level of number sense. With that knowledge, teachers need to improvise their teaching approaches and strategies to induce students' awareness and understanding of the mathematical procedures and concepts taught. The contention is that in order to make the tasks challenging enough (but not too difficult) for students to exercise their mathematical procedures and concepts, teachers must first understand what their students can and cannot do. As such, there is a need to selectively bridge misunderstandings and misconceptions among students based on the ideas that the students are struggling with. Consequently, as educators, we need to emphasize on students' process, not the outcome, of learning mathematics and derive our instructional decisions based on such emphases. This study has provided data on Malaysian upper grades students' (Secondary 2 and 4) level of comprehension of number sense and, as the findings suggest, the lack of comprehension of number sense among the students is a strident signal for teachers to make the necessary effort to bridge the dreaded disparity between procedural and computational skills and intuitive understanding in this crucial area of mathematical understanding.

Fostering the development of sense of numbers fundamentally involves the creation of an appropriate environment that comes from selecting and preparing specifically catered activities. The most important realization that can be drawn from this study is that children are not innately granted number sense upon birth. What this means is that teachers need to accept the fact that number sense needs to be specifically taught. The main question however is, in what way can number sense be taught? Or what kinds of teaching modes, approaches or strategies would facilitate the induction of number sense? More research needs to be carried

out to investigate the factors that inhibit students' sense of numbers in particular and their learning of mathematics in general.

Acknowledgements

The author(s) declare that they have no conflict of interest.

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