Revisiting decimal misconceptions from a new perspective: The significance of whole number bias in the Chinese culture

Mun Yee Lai\textsuperscript{a,}\textsuperscript{*}, Jeffrey P. Wong\textsuperscript{b}

\textsuperscript{a} School of Education, Australia Catholic University, Melbourne, Australia
\textsuperscript{b} Tatachilla Lutheran College, 211 Tatachilla Road, McLaren Vale, SA 5171 Australia

ARTICLE INFO

Keywords:
Decimal number misconceptions
Chinese number-naming system
Whole number bias
Decimal notation and quantities

ABSTRACT

The aim of this study was to investigate Hong Kong Grade 4 students’ understanding of the decimal notation system including their knowledge of decimal quantities. This is a unique study because most previous studies were conducted in Western cultural settings; therefore we were interested to see whether Chinese students have the same kinds of misconceptions as Western students given the Chinese number naming system is relatively transparent and explicit. Three hundred and forty-one students participated in a written test on decimal numbers. Thirty-two students were interviewed to further explore their mathematical reasoning. In summary, the results indicated that many students had mastered reasonable knowledge of decimal notation and quantities, which may be attributed to the Chinese linguistic clarity of decimal numbers. More importantly, the results showed that some students’ construction of decimal concepts have been adversely affected by persistent misconceptions arising from whole number bias. Two kinds of whole number misconceptions, namely “-ths suffix error” and “reversed place value progression error”, were revealed in this study. This paper suggests that a framework theory approach to conceptual change may be an alternative approach to addressing students’ learning difficulties in decimals.

1. Introduction

Chinese students consistently outperform their Western counterparts in many cross-national studies in mathematics achievement such as TIMSS (Beaton et al., 1997; Mullis, Martin, & Foy, 2008). These tests include test items concerned with decimal numbers (see for example, Mullis et al., 2008, p.119 and p.123). Many different explanations such as culture, language, students’ beliefs in mathematics learning, parental expectations, educational systems and practices, and teachers’ instructional pedagogies have been put forward to account for the Chinese students’ superior mathematics achievement. It is inevitable that language plays an important role in mathematics learning. Mathematical concepts and ideas are defined and expressed through language, and so are the connections between different mathematical ideas.

Scholars such as Alexander (1988) and Shuard (1983) have stated that, because of the complexity of mathematical language, misconceptions can result from those mathematical terms that have different meanings in daily life language and mathematical language. In spite of this, different cross-cultural studies (such as Han & Ginsburg, 2001; Miller, Major, Shu, & Zhang, 2000; Ng & Rao, 2010; Rasmussen, Ho, Nicoladis, Leung, & Bisanz, 2006; Stigler, Lee, & Stevenson, 1986) have repeatedly indicated that the Chinese number-naming system is relatively more consistent and explicit than other languages, such as English. In international mathematics
achievement tests, students from China, Japan and Korea, where their language show clarity and transparency in number naming system, have consistently demonstrated good mastery of mathematical concepts. Ginsburg, Choi, Lopez, Netley, and Chi (1997) argue that although many factors may contribute to their excellent performance, language factor should be considered as a key factor. Furthermore, the linguistic features of many Chinese mathematical terms are also relatively straightforward and transparent (Han & Ginsburg, 2001). Studies such as Han and Ginsburg (2001), and Miller, Kelly, and Zhou (2005) have reported that the relative clarity of Chinese mathematical language might contribute to Chinese students’ overall success in mathematics.

This paper is aimed at examining Hong Kong grade four students’ understanding of the decimal notation system and their knowledge of decimal quantities. This is a unique study since previous studies on the persistent misconceptions in decimal notation and quantities arising from whole number bias have been reported and described predominantly within Western cultural settings. However, it is not this study’s intent to make direct, cross-cultural comparisons of present and previous findings, but rather to apply previous findings into Chinese cultural settings to examine whether such misconceptions are also present within Chinese students, given that the Chinese linguistic features in decimals are relatively straightforward and transparent. The next section will examine the common misconceptions in decimal numbers revealed in different studies, followed by a discussion of the linguistic features of the Chinese number system, fractions and decimals.

2. Misconceptions in decimals and the framework theory approach to conceptual change

2.1. Misconceptions in decimals

In most school curricula, whole numbers and fractions are taught prior to decimals. Hiebert (1992) has pointed out that many students have acquired considerable knowledge of whole numbers and limited knowledge of fractions by the time they begin to learn decimals. Thus, the similarities and differences between whole numbers, fractions and decimals can both support and interfere with children constructing correct concepts of decimals (Resnick et al., 1989). (Refer to the study of Resnick et al. (1989) for the similarities and differences between the whole number knowledge, the corresponding decimal knowledge, and the corresponding fractional knowledge) More importantly, other studies such as Moskal and Magone (2000), Ni and Zhou (2005), and Stafylidou and Vosniadou (2004) have consistently revealed that when completing mathematical tasks involving comparing and computing rational numbers such as decimal numbers, students make many systematic errors because they misapply their knowledge of whole numbers to conceptualise and make sense of decimal numbers. Ni and Zhou (2005) and Vamvakoussi and Vosniadous (2010) denoted this kind of misconception as ‘whole number bias’ which is referred to as an interference of prior knowledge of whole numbers with the new concept of rational numbers.

Vosniadou and Verschaffel (2004) noted that elementary students have already firmly developed an initial concept of number before their first exposure to rational numbers. This initial concept of number is a complex knowledge system, it encompasses not only students’ existing whole number knowledge but also their beliefs of what counts as a number. When non-natural numbers are introduced, decimals and fractions are not ‘numbers’ in the same sense as students’ initial framework theory of number, even though they are still labelled ‘numbers’. Vamvakoussi and Vosniadous (2004, 2010) pointed out that when students find a newly learnt concept contradicting what they have already known, their use of additive mechanisms (i.e., assimilation, accommodation, internalization) of learning can destroy the coherence of the original knowledge structure. When the initial concept of numbers is further confirmed and systematised through students’ learning progress of whole number from kindergarten to junior elementary school (Greer, 2004), the learning of fractions and decimals may result in fragmentation of knowledge and formation of misconceptions due to the misuse of natural number reasoning to non-natural numbers. Building upon this, Vosniadous, Vamvakoussi, and Skopeliti (2008) explained that the cause of students’ misconceptions in rational numbers is principally due to addition of incompatible information to their initial concept of number, and subsequently the whole number bias is formed as a result. The students therefore perform decimal tasks accordingly with respect to natural numbers ordering and operations. In brief, students rely heavily on their initial understanding of natural numbers to make sense of rational numbers (Vamvakoussi & Vosniadous, 2010) and misinterpret decimals as near mirror images of whole numbers (Resnick et al., 1989).

Similarly, Irwin and Britt (2004) have also reported that many students’ misconceptions are the result of inappropriate generalisation from whole numbers and fractions. There are a number of incorrect “rules” children use when comparing the size of decimal numbers and these rules have been identified in several studies such as Desmet, Gregoire, and Mussolin (2010), Nesher and Peled (1986), Peled (2003), Peled and Awawdy-Shahbari (2009), Sackur-Grisvard and Leonard (1985), Stacey and Steinle (1999), and Steinle and Stacey (2010). In summary, Resnick et al. (1989) named these rules the Sackur-Grisvard and Leonard’s Rules 1, 2 and 3. The Sackur-Grisvard and Leonard’s Rule 1 (also known as the Whole-number rule or Longer-is-Larger rule) is the selection of the number with more decimal places as the larger decimal. It indicates that some students consider decimals as “another whole number to the right of the decimal point, with more digits representing a larger number” (Liu, Ding, Zong, & Zhang, 2014, p.326). The Sackur-Grisvard and Leonard’s Rule 2 (also known as the Fraction rule or Shorter-is-Larger rule) involves the selection of the number with fewer decimal places as the larger decimal. It indicates that some students consider the digit after the decimal point to be the denominator (Liu et al., 2014) and thus, smaller the denominator (i.e., less decimals places), and so the smaller the fraction (i.e., larger the decimal) (Baturo & Cooper, 1995; Desmet et al., 2010; Resnick et al., 1989; Stacey & Steinle, 1999; Stacey, Helme, & Steinle, 2001; Steinle, 2004a; Steinle, 2004b; Stacey & Steinle, 1998). Peled and Awawdy-Shahbari (2009) in their studies revealed a related but different error, namely a fraction unit conception in decimals, where participants “chose the shorter number as the larger one (0.4 > 0.67) with the explanation ‘because tenths are larger than hundredths’” (p.80). This type of error shows that some students focus on the parts (i.e., the fraction unit – tenths and hundredths) but disregard the number of parts in the decimals.
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات