PRINT: ISSN 0975-1122 ONLINE: 2456-6322
Int J Edu Sci, 15(3): 461-473 (2016)
DOI: 10.31901/24566322.2016/15.03.17

Challenges Faced by Entry-level University Students in Word Problems Involving Fractions Terminology

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KEYWORDS English. Language. Mathematics. Numeracy

ABSTRACT This paper emanates from a larger study undertaken at a South African comprehensive university. The aim of the study was to identify students' prior knowledge in fractions when they enroll for science and technology related diploma courses at tertiary institutions. This enables appropriate educational scaffolding. The study involved a sample of 94 first-year national diploma students out of a population of 120 students from three cohorts, namely, Civil and Electrical Engineering and Analytical Chemistry. Almost all the students had English as a second language in school. The instrument consisted of 20 items, three of which were multiple-choice questions (MCQs). The research design included a survey. The data was analyzed using Microsoft Excel 2013. Due to space constraints, this paper reports on the findings that a proportion of students exhibited difficulties with mathematical terminology when dealing with word problems on fractions.

INTRODUCTION

This paper emanates from a larger study undertaken at a South African comprehensive university. In the larger study, one of the sub-questions was, "What is the progression map of calculus-based foundation from school to university?" The researchers wanted to explore the links between university calculus for National Diploma courses in science and engineering and the mathematics in the General Education and Training (GET) and Further Education and Training (FET) bands.

It is common knowledge that 'a major proportion of learners studying at South African universities have insufficient grounding in mathematics and science' (Case 2006: 14). Although it "is reasonable to assume that students entering higher education would be numerically competent" (Jukes et al. 2006: 194), the researcher and her colleagues have for many years been convinced that misconceptions and lack of conceptual understanding of fractions were common amongst science and engineering students in their faculty. The researchers were interested in probing students' proficiency with fractions.

Furthermore, a report compiled in 2010 by the Engineering Council of South Africa (ECSA) stated that students entering university do so from positions of extreme inequality, most obviously in schooling, but also in terms of financial and other resources (ECSA 2010). The report maintained that the 'mix' of students and the range of challenges that students face, that is, academic, financial, social and so on, vary significantly across institutions, whilst the institutions themselves differ in important respects such as their staff composition, research profile, postgraduate enrolments, and different approaches to curriculum and to academic support (CHE 2010). The history, culture and resources of a particular university therefore play a role in the student body that it attracts and carries with it a unique set of challenges, more so in South Africa than in most other countries. An example of these differences is that second language instruction in mathematics differs from culture to culture (Gerber 2005).

Also, some twenty years ago, one of the researchers lectured computer skills. After a couple of years, the lecturer started lecturing mathematics to the same cohort of students. The vast majority of the students at this institution used English as an additional language. The observation was that students struggled more with communication and comprehension of instructions in computer skills than in mathematics. At the time, the English terminology involved in computer skills was unfamiliar to the students, who were mostly unaccustomed to computers. The difficulties with terminology produced problems with communication between the stu-

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dents and the lecturer. This was not the case with mathematics, since the students already had at least 12 years of instruction in mathematics and were more familiar with the English terminology used in mathematics. Due to this experience, the possibility of language interference in teaching and learning was noted. This paper investigates the challenges faced by entry-level students when confronted with English terminology related to fractions.

Objectives of the Study

The first objective was to identify students' prior knowledge in fractions when they enroll for science and engineering related courses. Identifying students' prior knowledge before commencing teaching is considered an educationally sound step in order to pitch the teaching at an appropriate level, and to enable appropriate educational scaffolding to enhance learning. If teachers consider differences in their students' understanding of fractions and are able to adapt their instruction to their students' prior knowledge, students' fractions skills and mathematics achievement will improve (Torbeyns et al. 2015).

The second objective was to probe the suspected language challenges that students faced when confronted with word problems in English, an additional language for most.

Review of Relevant Literature

The Importance of Numeracy

In this study, the terms "numeracy" and "quantitative literacy" are regarded as synonymous terms and are used interchangeably. Numeracy, and specifically proficiency with fractions, is an important part of mathematical preparedness. "Fractions (along with the closely related concepts of ratios and proportions) are ubiquitous in algebra" (Bailey et al. 2015: 1) and are therefore critical for success in algebra (Brown et al. 2006; Brown et al. 2007; Siegler et al. 2012a; Booth et al. 2014) and performance in later courses in mathematics (Booth et al. 2012; Siegler et al. 2012a; Watts et al. 2014; Torbeyns et al. 2015). Studies show that knowledge of fractions correlates with acquisition of algebraic skills and mathematics achievement in high school (Booth et al. 2012; Siegler et al. 2012b), which in turn influences career choices, eventual income levels (Titus 1995; Chow et al. 2015) and the likelihood of full-time employment (Rivera-Batiz 1992; Naureen et al. 2012). The importance of quantitative literacy has also been recognized by higher education and industry. The current approach is for university students to take at least one course on quantitative literacy, regardless of their field of study (Rhodes 2010). It is assumed that difficulties with numeracy will pervade studies in mathematics and science even at the tertiary level (NMAP 2008; Bailey et al. 2014), but the exact impact of problems with fractions in higher education is still unclear (Booth et al. 2014: 6) and needs to be researched.

Furthermore, difficulties with numeracy have been found to have a negative influence on adults in general. Ghazal et al. (2014) discovered a positive correlation between numeracy skills and medical and financial task performance in people's personal lives. They also found that a high level of numeracy decreased risk taking, such as in lotteries, since the statistical interpretations of the context and the consequences were better understood. The researchers further asserted a strong link between numeracy, confidence, deliberation and superior performance. As such, numeracy has been found to be a good predictor of judgment and decision-making in numerical and non-numerical tasks in real life, even amongst highly educated people. Numeracy influences performance and decision-making in personal and professional circumstances. Numeracy therefore affects not only mathematical studies, but also life in general.

International Studies on Numeracy

Investigating students' difficulties with fractions has been a topic of much research locally and internationally (Mdaka 2011; Fazio et al. 2014; Li 2014; Vukovic et al. 2014; Bailey et al. 2015). A nationally representative sample of a thousand Algebra teachers in the United States of America rated rational numbers as the major obstruction when considering their students' prior knowledge (Hoffer et al. 2007). Other large-scale studies have been employed internationally to determine, track and compare learners' skills levels in mathematics, such as Trends in International Mathematics and Science (TIMSS), Program for International Student Assessment (PISA), First International Mathematics Study

(FIMS) and SIMS (Second International Mathematics Study). Most of these studies were conducted with primary school and junior secondary school learners but others focused on adult numeracy skills, such as the Organization for Economic Cooperation and Development (OECD 2013). Fractions was one of the topics tested in the international studies, since it is a problem area in mathematics, and is indeed one of the most difficult topics for children to learn and for teachers to teach. In the 2015 TIMSS study on the fourth grade, fifteen percent of the fifty percent devoted to the number domain consisted of questions on fractions and decimals and in the eighth grade, two thirds of the number domain was devoted to questions on fractions, decimals, integers, ratio, proportion and percentages. Results will be analyzed and made available towards the end of 2016 and the data set will be published in February 2017.

Difficulties with Numeracy in South Africa

South African learners already display a skills deficit early on in their schooling career. In a project launched in 2001, the Department of Education evaluated the numeracy and literacy skills of a sample of Grade three learners, from urban schools, farm schools and rural schools all over the country (Clynick et al. 2004). The learners' average score on the numerical test was thirty percent. Already, after only four years of learning and teaching, serious problems were apparent in concept development. Furthermore, in Grade four tests conducted from 1998 to 2002 by the Joint Education Trust (JET), the learners scored an average of thirty percent in numeracy, the lowest of 12 countries tested (Clynick et al. 2004). Very poor results were also obtained on Grades five, six, seven, nine and eleven (Clynick and Lee 2004). All the tests had to be simplified after results from pilot studies indicated that learners could not cope with the degree of difficulty of the original tests.

South African learners have also performed poorly in the international comparative studies. In the 2011 TIMMS test, almost a third of the Grade nine South African pupils (32%) performed worse than guessing on the multiple choice items (that is no better than random). Furthermore, more than three quarters (76%) of Grade nine pupils in 2011 had not acquired a basic understanding of whole numbers, decimals, operations or basic graphs. This was despite the fact that the Grade nines wrote the Grade eight test, because it was agreed that the test was too difficult for the Grade eights (Spaul 2013).

Problems with fractions are not necessarily resolved before adulthood (Rittle-Johnson et al. 2001). Schneider et al. (2010) found that community college students in the United States answered correctly on only seventy percent of questions involving comparisons of fractions. Furthermore, studies reveal that even prospective teachers of mathematics struggle with fractions (Bailey et al. 2015).

Language

Language is one of the domain-general competencies that influence learning in all academic domains, also in mathematics (Whang 1996; Gerber 2005; Vukovic et al. 2014). Mathematics and language are closely interlinked (Pimm 1987) and mathematics scores have been shown to improve as reading ability improves (Bohlmann et al. 2002). In a study done more than 10 years ago at a South African university, it was shown that poor readers only achieve "reading comprehension levels of fifty percent or less, which means that half of what they read they do not properly understand, with dire consequences for their academic performance" (Bohlmann et al. 2002: 204). In a recent international study, Ercikan et al. (2015) examined the relationship between reading proficiency and performance on mathematics and science assessments of students with English as first language and students with English as additional language. Findings indicated a strong relationship, with reading proficiency accounting for forty-three percent of the variance in mathematics. When statistical adjustments were made for reading proficiency, the score gap between the groups became statistically insignificant in three of the four countries included in the study. Language and communication, along with mathematics, were found to be some of the most commonly cited challenges facing students at South African universities (CHE 2010). According to the National Reading Strategy (DoBE 2008: 4), some university students are not proficient readers in terms of international standards, which in turn leads to poor academic performance (Bharuthram 2012). Similar findings were reported by other researchers at South African universities (Pretorius et al. 2004; Howie et al. 2007; Nel et al. 2010).

Research on language interference in numeracy in tertiary contexts seems to be limited. In fact, the researchers struggled to locate studies conducted on the numeracy skills of science or engineering students in higher education. Studies seem to focus more on language problems in mathematics, not numeracy specifically. One study (Ewing et al. 2009), conducted respectively at a community college in the United States and a university in Oman, examined the language difficulties experienced by second language learners when studying mathematics based courses in English. The university students from Oman were enrolled for courses in science, engineering, medicine, agriculture and commerce and completed their secondary schooling in Arabic. When comparing the two institutions, the researchers reported "extraordinary parallels in the students' deficiencies in the language of math, despite the vastly dissimilar contexts" (Ewing et al. 2009: 72).

It seems that most people equate proficiency in mathematics to being quantitative literate, which is not necessarily the case (Barwell 2004; Houston et al. 2015). Roohr et al. (2014) assert that quantitative literacy is embedded in real-world contexts, and therefore lacks the more abstract and general nature of mathematics. Because of the context-based nature, quantitative literacy is therefore more language dependent than mathematics, and mainly assessed as word problems.

Mathematics as a Language

Pimm (1987) asserts that mathematics is in fact a language, also referred to as the mathematical register, and therefore additional language speakers have to deal with the complexities of three languages simultaneously, that is, their mother tongue, the additional language, and mathematics. Prediger et al. (2013) identified a further language register, the so-called school register or "language of schooling" (Fang et al. 2006: 247). This register is a hidden, intermediate register of higher complexity, and may not be readily available to additional language learners from poor academic backgrounds (Clarkson 2009).

Problems in the mathematical register abound. Some words sound alike. The differences are subtle and difficult to detect for additional language speakers, such as the difference between *hundreds* and *hundredths*. Words used in a mathematical context may change meaning, such as round (to two decimal places) and round (circular). *Left*, as in 'How many are left?' is often incorrectly interpreted as 'how many have been removed' or 'how many have left an area' (Ewing et al. 2009: 75). Phrases and words in mathematics have very precise meanings, such as *at most*, *at least*, *not more than*, *greater than*; *greater than or equal to*, 'and' implying intersection; 'or' implying union. Students often interpret phrases incorrectly. 'One out of ten' is often understood as nine, the amount after one was subtracted (Ewing et al. 2009: 75). Word order and prepositions cause difficulties with interpretation. The difference between 'subtract a from b' and 'from b subtract a' are subtle, but crucial. A preposition could change the intended meaning altogether, such as *prices increased **by** or **from** or **to** R50*; *divide a **by** b* versus *divide a **into** b* (Table 1). To complicate matters, mathematics borrows words from colloquial language and adds a further level of complexity by changing the meaning of words and using it in a different context, for example revolution, table, matrix (also the name of a movie familiar to some university students), plus minus (which means approximately in colloquial English but in mathematics refers to two answers of the same magnitude which are opposite in sign) and expand, among others (Kotopoulos 2007).

Although all the terms and phrases in Table 1 do not directly reference fractions and their related topics, they do elucidate the possible language interference caused by the mathematical register's unique application of vocabulary and grammar. There is no reason to assume that the difficulties will be any different for fractions, since the language of fractions is especially complex and affects the mutually symbiotic relationship between the procedures used to manipulate fractions and the conceptual understanding of the procedures (Jordan et al. 2013). In a study on deaf and hard of hearing learners, learners between the ages of 10 and 16 presented a low level of understanding of fractional numbers, which was ascribed to their limited access to mathematical terms in spoken and printed English (Titus 1995). The following language concepts were listed as problematic for the deaf or hard of hearing students, that is, "Use of

Table 1: Language difficulties in learning mathematics

Difficulties	*Examples*
Distinguishing between words that sound similar	hundreds; hundredths
The meanings of words change according to the context	left, as in "How many are left?" is often interpreted as "How many have been removed?" or "How many have left an area?" (Ewing et al. 2009: 75); right; plus minus; round (to two decimal places) and round (circular)
Understanding the precise meanings and the mathematical importance of words and phrases	at most; at least; not more than; greater than; greater than or equal to; "and" implying intersection; "or" implying union; "one out of ten" is often interpreted as nine, the amount after one was subtracted (Ewing et al. 2009: 75)
Word order	subtract *a* from *b* or from *b* subtract *a*
Understanding the significance of prepositions	prices increased **by** or **from** or **to** R50; divide *a* **by** *b* or divide *a* **into** *b*

Source: Authors

conditionals, comparatives, negatives and inferentials (such as knowing boys and girls are children)" (Marschark et al. 2010: 161). Titus (1995) found that deaf and hard of hearing learners consequently tried to avoid fractions, especially when ratios were involved.

According to Prediger et al. (2013), poor early language competency complicates the conceptual transition from whole numbers to fractions, indicating that a good grasp of mathematical language underpins the development and assimilation of new skills. Not only are language systems important for learning vital vocabulary like the names of fractions (halves, thirds) and the verbal count sequence, but construction of meaning happens through language and is a significant gateway to the construction of new knowledge (Jordan et al. 2013). Learners, who learn mathematics in an additional language from an early age, may therefore struggle with the added levels of complexities and may be impaired in ways that teachers and researchers do not yet appreciate. Prediger et al. (2013) determined that proficiency in the language of instruction was of greater importance than other factors, such as immigrant status or multilingualism.

METHODOLOGY

The study involved first-year students from a comprehensive university in South Africa's Eastern Cape Province who were enrolled for mathematics, a mandatory course for diploma studies in science and engineering. The sample consisted of 94 (out of a population of 120) students from three cohorts, namely Civil Engineering, Electrical Engineering and Analytical Chemistry. The students belonged to one of two streams, the mainstream and the extended stream. The extended stream allows students, who do not qualify academically for the entrance requirements of their chosen course and are allowed extra time to complete their studies. These courses qualify for additional government subsidies. English was an additional language for all except two of the students from the sample.

Research Design

The research design was a survey, which was completed by the members of the sample on a pre-arranged date at two of the delivery sites of the institution. The instrument consisted of 20 items, including three MCQs and 17 were open-ended items. The measuring instrument was compiled by the lead researcher after a study of the pertinent literature on pre-algebra, with the emphasis on fractions. Questions from various TIMMS studies were analyzed with regard to their International Difficulty Index (IDI) or International Average (IAVE) score. Questions were selected to test skills in the following categories of notation, magnitude and magnitude on a number line, operations on fractions, operations combined with SI unit conversions, ratio and proportion, percentage, and percentage increase and decrease.

The skills tested are required in most engineering courses and sciences, but even more so in the module on introductory statistics, which forms a part of the mathematics syllabus for two of the cohorts of students included in this study. The test was scrutinized by four experienced mathematics lecturers, and their suggestions were implemented. They were then requested to rate the expected performance of the students in each question in the questionnaire as either very easy, easy, moderate, difficult or very difficult. All the lecturers involved in this study indicated that students in their courses struggled with fractions, yet rated the items as mostly very easy, easy or moderate (85.5%). Only 14.5 percent items were rated as difficult or very difficult. The test was then piloted. When data was analyzed after the pilot study, it became clear that language difficulties were apparent in some questions, and a few questions on the test were adjusted in an attempt to reveal these more clearly. This paper focuses on those questions.

Data Collection

The test was done during a pre-arranged two-hour time period. Field workers administered and invigilated the test to comply with ethical requirements of the university. They explained to the students that their participation was voluntary and that the test would be written anonymously. This information was also printed on the test. Demographic and background data was gathered from students, for example, age, Grade 12 mathematics scores, gender, course and stream (mainstream or extended stream). In the pilot study conducted in the previous year, all students completed the test in less than an hour. No time limit was however put on the test, since data needed to be collected on every question and the researchers did not want the lack of time to be a limiting factor in the data collection. Calculators were allowed, since students studying for the diplomas in question are allowed to use calculators in all of their courses and assessments.

RESULTS

The data was analyzed using Microsoft Excel 2013. A total of 54 (57.4%) of the students were in the mainstream and 40 (42.6%) from the extended stream. The gender division of the sample was 48 (51.1%) males and 46 (48.9%) females. The majority (55 or 58.5%) of the students were in the 20 to 24 years age category and a further 33 (35.1%) in the 15 to 19 years age category. The engineering students comprised 47.9 percent of the sample, and the rest (52.1%) were analytical chemistry students. The self-reported Grade 12 results indicated that 32 (34.0%) students of this cohort scored below fifty percent in mathematics in Grade 12 and these students were therefore considered to be at risk. A further 27 students (28.7%) scored between fifty and fifty-nine percent and were considered to be in need of support. A total of 37.2 percent students achieved sixty percent and above. A minority of the students (40 or 42.6%) reported that they were confident when working with fractions, while 44 (46.8%) were unsure. These figures correlated with students' scores in the test, the average test score being 47.8 percent, with a standard deviation of 19.6 percent. Most of the students in the sample (70 or 74.5%) were dissatisfied with their Grade 12 mathematics results. The vast majority (86 or 91.5%) of this sample of students regarded mathematics as very important for their chosen careers.

The average score for the test was 47.8 percent. The score was regarded as disappointingly low, especially considering that the test was pitched at a Grade eight level. It therefore seems safe to state that difficulties with fractions persisted into adulthood, even for science and engineering diploma students at the entry level.

Answers to individual questions were checked and scrutinized for possible language interference. Because of space constraints, only the questions that revealed language difficulties in the pilot test were discussed in this article. Language difficulties were apparent from steps written down by students and the answers given. If the question was, "What is 5 divided by one quarter?" and the student wrote, "5/1.25, or 5 ÷ 5/4, or $5 \div 1\frac{1}{4}$ then it was clear that the student divided by one and a quarter, not by one quarter.

The first question tested mathematical notation and whether students were able to use the appropriate notation correctly (DoBE 2011b: 16). Two proper fractions were given and students had to pick the correct sign (less than, $<$, more than, $>$, etc.) to insert in the placeholder between the two fractions.

If 3/4 is more than 2/6, which sign must replace the placeholder in the following statement?

$\frac{2}{6} \square \frac{3}{4}$

a) <
b) >
c) =
d) ≥

A majority of students (66 or 70.2%) answered this question correctly (Table 2). There was a substantial difference between the mainstream (46 correct or 85.2%) and the extended stream (20 correct or 50.0%). All the incorrect answers were choice b, which indicated a problem with mathematical symbolic notation, a feature of the mathematics register of language, which includes symbols, pictures, diagrams, words and numbers. Similar results were reported by researchers from a university in Argentina (Sastre-Vazquez et al. 2013), who found that students taking part in their study had a limited understanding of mathematical symbols.

In Questions 3a and 3e students were expected to divide an integer by a fraction (DoBE 2011a: 101). The questions were separated by other questions, since the author of the test attempted to avoid an implied association between the two questions and did not want the first question to act as a clue to the second question.

Q3a) How many quarter-liter containers can be filled from a 3-liter container?

Q3e) What is 5 divided by one quarter?

Both questions tested division of a whole number by a fraction, with the difference that Question 3e indicated the required operation as division, but Question 3a did not, and students had to identify the required operation from the context. The scores for Question 3a were equally low for both streams, with a score of 40.7 percent for the mainstream, and forty percent for the extended stream (Table 3). It is however interesting to note that while the extended stream performed very poorly in the first question, results were reversed in the second, with the extended stream scoring higher than the mainstream in the second question.

When answering these two questions, between five percent and ten percent of students made the mistake of using 1/3 instead of 1/4 for one quarter. In Question 3a, 5 (5.3 %) stude nts made this mistake, and hence divided by a third to get 9 as an answer. In Question 3e, nine of the students (almost 10%) used instead of for one quarter. It is not clear why more students made this particular mistake in the second question than in the first, but it is reasonable to assume that students were unsure of the English terms for fractions. Problems with English language terminology thus negatively influenced their performance in word problems. Qualitative methods were not employed in the study, and this limited further probing of specific misconceptions encountered.

Furthermore, when answering the second question, eight students (almost 9%) divided by 1.25, which is one and a quarter, not one quarter, and hence ended up with 4 as an incorrect answer. Between five percent and nineteen percent of this cohort of students thus made mistakes that were apparently caused by an inadequate grasp of mathematical terminology in English. There may possibly be more such problems that went undetected, since it is sometimes difficult, if not impossible, to determine the cognitive steps followed by students to reach a specific answer without interviewing the student. It is thus not always possible to separate language difficulties from other difficulties experienced by students.

In a following problem (Questions 3c and 3d), students were tested on rounding skills. In both parts of this question, students were requested to round a given decimal number to a required number of decimal places. These were

Table 2: Scores for question 1

N = 94	*Mainstream (54)*			*Extended stream (40)*	
	Electrical Engineering (20)	*Civil Engineering (17)*	*Analytical Chemistry (17)*	*Civil Engineering (8)*	*Analytical Chemistry (32)*
Correct answers	19 (95.0%)	14 (82.4%)	13 (76.5%)	4 (50.0%)	16 (50.0%)
Correct answers per stream	46 (85.2%)			20 (50.0%)	
Total			66 (70.2%)		

Source: Authors

however indicated in mathematical language terminology (the nearest hundredth) in the first question, and specified as a number (3) in the second question.

Q3c) Round 0.6666 off to the nearest hundredth.

Q3d) Round 0.7797 to 3 decimal places.

The assertion that mathematical terminology was problematic, was confirmed by the relative success that students had with the more difficult rounding procedure in the second question, which was answered correctly by 66 (70.2%, n = 94) students, yet the students struggled to round to the nearest hundredth in the first question. Only 14 (14.9%, n = 94) students who attempted to answer this question, answered correctly. The vast majority of the answers were incorrect, and a small number of the students (4 or 4.3%, n = 94) did not attempt the question at all. All calculations of percentages were based on n = 94, even if students did not answer the question. In such cases it was assumed that students could not answer the question, since students were given almost unlimited time (Wilson et al. 2007).

Most students did not know how to proceed to answer the question, as the following examples indicate. John (not his real name) seemingly confused rounding with multiplication, and effectively multiplied by 100 (Fig. 1).

However, the most feasible explanation for John's answer is that he did not know the difference between rounding to the nearest hundred and rounding to the nearest hundredth. He focused on the 100 and proceeded to multiply by 100. It is difficult to rule out other explanations without interviewing students, which was not done in this study, since students wrote the tests anonymously.

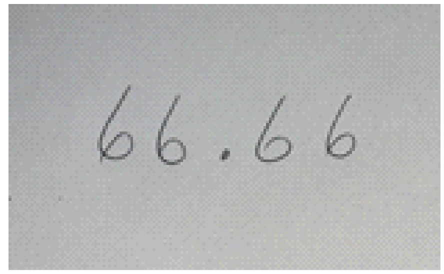

Fig.1. John's attempt at rounding off to the nearest hundredth
Source: Coetzee

Andile made an attempt to show the digit representing the hundreds (the left-most digit in his answer), although he did not know what to do with it (Fig. 2). He did round, but not correctly.

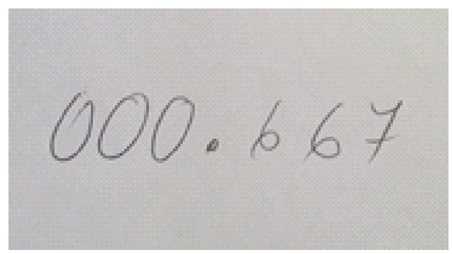

Fig. 2. Andile's attempt at rounding off to the nearest hundredth
Source: Coetzee

It remains disconcerting that 29.8 percent of the sample of science and engineering students at entry level, could not manage to round a decimal number correctly to three decimal places, a skill which is prescribed in the Grade seven syllabus (DoBE 2011a: 19).

Table 3: Scores for the questions on division by a fraction, Questions 3a and 3e

N = 94	*Mainstream (54)*		*Extended stream (40)*		
	Electrical Engineering (20)	*Civil Engineering (17)*	*Analytical Chemistry (17)*	*Civil Engineering (8)*	*Analytical Chemistry (32)*
Question 3a	8 (40.0%)	9 (52.9%)	5 (29.4%)	1 (12.5%)	15 (46.8%)
Totals per stream	22 (40.7%)	16 (40.0 %)			
Totals	40.4%				
Question 3b	15 (75.0%)	10 (58.8%)	13 (76.5%)	7 (87.5)	25 (78.1%)
Totals per stream	38 (70.4%)	32 (80.0%)			
Totals	74.5%				

Source: Authors

DISCUSSION

The data in this study indicated that between five percent and nineteen percent of students struggled with mathematical terminology in English on various questions containing fractions. McLean (2000) reported similar results, asserting that students displayed an inadequate knowledge of basic vocabulary. In a study conducted by Barton et al. (2005) in New Zealand with additional language students, it was found that language difficulties caused a disadvantage in mathematics of ten percent, in line with the problems experienced in the study of other subjects. The belief that mathematics is exclusively numerical is therefore erroneous. Similar studies found the size of the disadvantage to be between ten percent and twenty percent (Barton et al. 2009), but a more recent study (Ercikan et al. 2015) ascribed at least forty-three percent of the variation between mathematics scores of first language speakers and those of additional language speakers, to differences in the reading proficiency of the two groups. It is therefore reasonable to state that more language difficulties with numeracy remain undetected than those accounted for in this study (Table 4).

Table 4: Challenges: Similarities and differences in terminology

Similarities	
Round to two decimal places	Round to the nearest hundredth
Differences	
Round to the nearest hundred	Round to the nearest hundredth
One half	One and a half
The nearest 10	The nearest tenth

The magnitude of the disadvantage in mathematics reported in this paper may seem insignificant, but low pass rates and poor conceptual understanding in mathematics remain problematic in South Africa, and any information on how to address these, may be valuable. If a proportion of tertiary students in the sciences experienced these problems, it is safe to state that even more Grade 12 students were affected by the same difficulties, which may have played a role in their exclusion from tertiary studies. It is worth noting that only seventeen percent of the Grade 12 cohort in 2009 participated in tertiary education (Case et al. 2013), and raising the English language entry standard of first-year students as recommended by Boreland (2016), is therefore not an acceptable way forward. Besides, difficulties with terminology may be relatively easy to overcome, and once remedied, may have a positive effect on the future educational experience of the individuals involved. Also, these findings are significant in the South African language context, since fewer than ten percent of South Africans are English first language speakers and 10 other languages are recognized as official languages. The multiplicity within the group of additional language learners complicates the matter of learning via an additional language even more (Naudé et al. 2005: 2).

Researchers agree that students' mathematical vocabulary learning is a very important part of their language development and ultimate mathematical proficiency (Riccomini et al. 2015). It is clear that the language in which mathematics is taught, can be a barrier to learning (Pimm 1987; Setati et al. 2008). It is also reasonable to assume that many more language difficulties remain undetected. Early detection of common difficulties amongst second language speakers is vital, and should be shared amongst the community of mathematics educators. According to researchers (Chan 2015; Simpson et al. 2015), it is important for teachers to be aware of the linguistic challenges and to provide guidance on how learners can overcome these. Programs are needed to enhance learners' proficiency in the technical register of the language of instruction from an early age (Thürmann et al. 2010). Rubenstein-Avila et al. (2015) encourage bilingual students to solve problems collaboratively to promote student communication and language development. Mathematics teachers and English language teachers should collaborate to promote second language learners' awareness of the language of mathematics. Mathematics teachers should also encourage bilingual students to solve problems collaboratively while promoting student debate and participation in English. It is expected that such discussions will improve vocabulary development in English. Similarities and differences between words and phrases have to be made explicit, such as those in Table 4. Interventions could be far-reaching, such as raising the English language entry criteria of first-year students, or simple, such as providing a glossary of mathematical terms to entry-level university students. Lecturers should work through these with the students, especially extended stream students, since explanations will be required. English designations of fractions should be memorized at an early age and terminology should be reinforced regularly. Furthermore, the English names for decimal fractions, such as a tenth, hundredth and so on, should be used together with statements instructing students to round to a given number of decimal places in order to foster a strong association between the phrases. It is important for teachers to be aware of linguistic challenges and to provide guidance on how learners can overcome these.

The importance of the early school years cannot be overemphasized. Mathematics is by nature accumulative. Bailey DH et al. (2015) refer to the accumulation of learning opportunities based on prior learning as a "cascade of learning events". These events will continue as part of lifelong learning, and will continuously be influenced by what took place in early childhood education. Watts et al. (2014) emphasize that early mathematical and reading skills are important predictors of learners' long-term achievement in mathematics. More specifically, Vukovic et al. (2014) assert that language competencies in the early school years may enable learners to master the finer nuances of number in the later grades, such as the differences between 5 and 1/5 and hundreds and hundredths. All teachers have to focus on aspects of language competence, since "each teacher is a language teacher and therefore language and comprehension must be emphasized in each subject classroom" (DoBE 2014: 5). The mathematics teacher is not expected to teach English, but rather to teach the language needed to learn mathematical concepts and skills (Cuevas 1984). Emphasis should be on comprehension rather than just terminology (Setati 2005). According to the TIMMS Mathematics Framework (2011), students would find purposeful mathematical thinking impossible if they lack a knowledge base that enables easy recall of the pertinent language and symbolic representation. Memorization of basic terminology in mathematics remains crucial. Mousley et al. (2015) insist that rote memorization of terminology plays a large part in students' ability to comprehend fractions, and Ewing et al. (2009) concur that repetition in second language learning is invaluable.

CONCLUSION

The data in this study indicated that this cohort of science and engineering students at entry-level to university struggled with quantitative literacy and that problems with fractions had not been resolved. It was found that between five percent and nineteen percent of students struggled with mathematical terminology in English with various questions containing fractions.

FOR FUTURE STUDIES

As already mentioned, it is reasonable to assume that many more challenges related to terminology in mathematics and numeracy remain undetected. Future studies should attempt to identify these. The extent to which difficulties with fractions impacts studies in mathematics and related subjects of science and engineering university students, needs to be explored. As already mentioned, the history, culture and resources of a particular university play a role in the student body that it attracts and carries with it a unique set of challenges, more so in South Africa than in most other countries. This study can therefore not be generalized to other tertiary institutions without further research. Research should investigate whether challenges with fractions terminology is common amongst entry-level South African university students.

RECOMMENDATIONS

It is evident that not all science and engineering entry-level students at university are familiar with mathematical terminology and lecturers should not assume that they are. Mathematical terminology should thus be reinforced when working with entry-level university students, especially those for whom English is an additional language and the extended stream students. Further subject and topic specific research is required to determine explicitly which technical language challenges are prevalent amongst entry-level students and which interventions will be most effective.

LIMITATIONS

The current study did not make use of interviews or other qualitative methods, and interpretation of student errors was therefore limited. There was clearly a need to probe the procedures and thought processes behind the procedures. Interviews with students would have been useful, and elicit the more detailed conclusions regarding the range and variety of language difficulties with fractions.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support for the research and publication of this paper from the Walter Sisulu University (WSU) and the University of Fort Hare (UFH).

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Paper received for publication on January 2016
Paper accepted for publication on November 2016