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Language of Learning and Teaching as one of the Causes for Difficulties in Learning Fractions

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Abstract: This paper evolved from a larger study and aimed to test the fractions skills of entry-level students at a South African comprehensive university. The focus in the paper is on the language of learning and teaching as one of the causes for difficulties in learning fractions for entry level science and engineering students. The sample consisted of 94 entry level students out of a population of 120, who enrolled for national diplomas in science and engineering. The survey instrument consisted of 20 items and the data were analyzed using Microsoft Excel 2013. The main findings were that entry-level students enrolled for engineering and science diploma courses struggled to apply fraction arithmetic and that the problems associated with the language of learning and teaching (LoLT) caused difficulties. This study provided important information to school- and university-level mathematics educators by confirming that language difficulties can negatively impact upon the success in learning fractions.

Keywords: Difficulties in Learning Fractions, University Entry Level Students, Language of Learning and Teaching

1. Introduction

The purpose of the study was to investigate if the language of learning and teaching (LoLT) was a cause for difficulties in learning fractions for entry level science and engineering students. In this paper, the terms ‘numeracy’ and ‘quantitative literacy’ were regarded as synonymous terms and used interchangeably.

1.1. Difficulties in Learning Fractions

The mathematics education literature has recently focused on deliberations on university students’ difficulties with fractions. One of the issues under scrutiny was whether difficulties experienced with fractions at earlier stages of the educational process have been resolved by the time students enroll at university [1], [2], [3], [4], [5], [6].

Researchers in diverse fields such as nursing and health sciences [4], business [7] and law [3] have reported perturbing results with respect to students’ insufficient fraction skills. Clearly, students in different fields of study struggle with the numeracy demands of their courses. However, research reports on the numeracy demands of science and engineering courses have been sparse, probably due to the assumption that competency in mathematics necessarily encompasses high levels of quantitative literacy. It is however crucial not to make assumptions about entry-level students’ skills levels, since incorrect assumptions may detrimentally influence the academic progress of the students. “It is important for higher education educators to understand the quantitative literacy (QL) competencies of incoming students, in order to make appropriate assumptions about prior knowledge and to design suitable curricula” [10].

1.2. Language and Mathematics

Citing [9], [8] states that, “Mathematics education begins in language, it advances and stumbles because of language, and its outcomes are often assessed in language”. At least some measure of poor performance in mathematics in the earlier grades has been ascribed to teaching and learning in an additional language. Research has shown that proficiency in the lingua franca of a particular country is predictive of eventual attainment of employment and also of eventual income levels [11]. Since the majority (more than 90%) of learners in South Africa speak English as a second language and get their schooling in English which is the Language of Learning and Teaching (LoLT), access to higher education and the labor market depends on becoming fluent in English [12].

Evidence shows that language proficiency has an influence on mathematics achievement on the primary and secondary level [20], [13], [19], [18]. Language issues become even more prevalent in mathematics when word problems are under consideration. Various studies have found that the majority of errors made when solving mathematical word problems were due to lack of comprehension of the text and not necessarily computational errors [24], [27], [31].

Countries with multilingual populations, such as India, Papua New Guinea, Indonesia, Nigeria and South Africa have millions of students who are schooled in a language other than their mother tongue. 'This makes the need to understand the link between language, cognition, and academic performance all the more important" [8]. Two research studies conducted in Papua New Guinea report that students had difficulties with word problems [16]. The authors of the first paper [8] attribute these problems to students' inefficient proficiency in English, and specifically with mathematical English as reported [26]. In the other study, the author [25] attributes students' poor performance in solving word problems to a lack of mathematical vocabulary. This finding was confirmed by a study conducted in South Africa [32]. In yet another study conducted in South Africa, error analysis was done on the results of a National Certificate (NC) examination in Mathematical Literacy. In this examination, 32% of the errors made by English second language students, were ascribed to limited language proficiency [18]. Comprehension difficulties may arise from the presence of unfamiliar (low-frequency) words, polysemous words (words or phrases which have more than one or several meanings) and idiomatic or culturally specific lexical references [28].

2. Methodology

2.1. Sample

The sample consisted of 94 (out of a population of 120) first year students at entry from three cohorts, namely Civil Engineering, Electrical Engineering and Analytical Chemistry at a comprehensive university in South Africa. Anonymity was guaranteed. Only those students who volunteered were included in the sample. Mathematics is a mandatory course for diploma studies in science and engineering. The students belonged to one of two streams, the mainstream and the extended stream. English was an additional language for all except two of the students from the sample. The number of students in the sample were 54 (57.4%) and 40 (42.6%) from the mainstream and the extended stream, respectively. The engineering students comprised 47.9% of the sample, and the rest (52.1%) were analytical chemistry students.

2.2. Research Design and Instrument

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 a South African Comprehensive University. The instrument consisted of 20 items, including three Multiple Choice Questions (MCQs) and 17 open-ended items. Questions were selected to test skills in the following categories: 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 test was scrutinized by four experienced mathematics lecturers, who were also requested to rate the level of difficulty of the questions as either very easy, easy, moderate, difficult or very difficult. All four had indicated that students in their courses struggled with fractions and yet rated the items as mostly very easy, easy or moderate (85.5%). Only 14.5% items were rated as difficult. None had a very difficult rating. Hereafter, the test was piloted. When the data were 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 make them clearer than before. This paper focuses on data on those questions modified after piloting. The test was administered at the beginning of the semester.

3. Results

The average score in the fraction skills test of 47.8% was unsatisfactory, indicating that most entry-level engineering and science diploma students at this particular university in South Africa still struggled with fractions. The scores had a wide range (7%-86%). The standard deviation and the median were 19.6 % and 50.5%, respectively. Only 31.9% of the cohort scored above 60% in the test (Table 1) and amongst them, the Civil Engineering group members were the most (11 or 44%).

Table 1. *Distribution of test scores of cohort.*

Test Scores	Group							
	Analytical Chemistry		Civil Engineering		Electrical Engineering		Total	
0 to 19	6	12.2%	2	8.0%	0	0.0%	8	8.5%
20 to 39	18	36.7%	4	16.0%	4	20.0%	26	27.7%
40 to 60	12	24.5%	8	32.0%	10	50.0%	30	31.9%
61 to 80	11	22.4%	10	40.0%	6	30.0%	27	28.7%
81 to 100	2	4.1%	1	4.0%	0	0.0%	3	3.2%
Total	49	100%	25	100%	20	100%	94	100%

When asked whether they were confident when working with fractions, 43% of the students expressed confidence (Table 2). These figures point to overconfidence levels, since only 3 students (3.2%) scored over 80% in the test, the minimum benchmark agreed upon amongst the lecturers who scrutinized the test. This shows that simply believing students' statements such as 'I am confident' can be misleading unless proved otherwise.

Table 2. *Confidence levels of cohort with respect to fractions.*

I am confident	Group							
	Analytical Chemistry		**Civil Engineering**		**Electrical Engineering**		**Total**	
Strongly disagree	0	0%	1	4%	1	5%	2	2%
Disagree	7	15%	0	0%	0	0%	7	8%
Neutral	20	43%	16	64%	7	35%	43	47%
Agree	15	33%	6	24%	9	45%	30	33%
Strongly Agree	4	9%	2	8%	3	15%	9	10%
Total	46	100%	25	100%	20	100%	91	100%

The results of the error analysis of students' scripts revealed that some errors can be attributed to lack of language proficiency. The first question tested mathematical symbolic notation and whether students were able to use the appropriate notation correctly as expected by the Department of Basic Education [14]. Notation is a feature of the mathematics register of language, which includes symbols, pictures, diagrams, words and numbers. Two proper fractions were given and students had to pick the correct sign (such as less than, <, or more than, >) to insert in the placeholder between the two fractions. This question was rated by lecturers as easy, and the majority of students (66 or 70.2%) answered it correctly

It is not always simple to categorize the source of a particular error, since they interact and overlap [15] as cited by [18]. Problems experienced by students when answering this question can be attributed to poor fraction magnitude comparison strategies, or difficulties with mathematical symbolic language. Symbols are used to condense statements and concepts into a mathematical form that can be manipulated. Statements containing symbols have their own syntax. This syntax is not always well understood by students. A researcher [16] quotes another [17], who explains that,

> … mathematical symbolism has a grammar of its own: For example, the mathematical statement "2 < X < 8" is totally "grammatical" within the symbolic language of mathematics; however, the variation "2 < X > 8" is ambiguous since it states that X > 2 and X > 8, both of which cannot always be satisfied simultaneously. Further, the variation "2 > X > 8" is not grammatical since it implies that X < 2 and X > 8, either of which contradict the other.

Comparable results were reported by researchers from a university in Argentina [21], who came to the conclusion that students had a limited understanding of mathematical symbols. There was a marked difference between the ratio of correct answers given by mainstream (46 correct or 85.2%) and the extended stream (20 correct or 50.0%). Yet another misconception involving mathematical symbols, was to transcribe a mixed fraction incorrectly to a decimal fraction, for example, $3\frac{1}{4}$ was transcribed as 3.4. This mistake was also more common amongst extended stream students.

Problems with mathematical terminology were apparent in a following question, in which students had to round off a given decimal number, first to two decimal places, and then to the nearest hundredth. Most students did not know the term 'nearest hundredth' and also did not know that it differed from the term 'nearest hundred'. The majority answered the first question correctly (66 or 70.2%, n = 94), whereas only a few students answered the second question correctly (14 or 14.9%, n = 94). It was evident that some students were not confident when using English terms for fractions. Almost 10% of students used $\frac{1}{3}$ when the test text referred to one quarter. Others used $\frac{5}{4}$ in calculations when the text referred to *one quarter*. These students confused *one quarter* with *one and a quarter*. Problems with English language terminology thus detrimentally influenced performance in word problems.

It is important that mathematics teachers and researchers collaborate to identify language challenges in order to design an effective pedagogy to address these. With reference to first and second language speakers, [29] ascribed 43% 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. Various studies found that increased exposure to mother tongue instruction has positive and significant impacts on income, literacy and numeracy [11].

Questions that are cognitively undemanding to a native speaker will be more demanding for a second language student [22]. Scaffolding of the mathematical language of second language students should become standard practice. Teachers should use strategies to teach students the language of mathematics and ways to read and interpret word problems [23]. We need to employ effective pedagogical approaches in multicultural and multilingual classrooms [30]. Care should be taken when compiling assessments. A high-level command of the English language should not be a pre-requisite for valid and fair assessments.

4. Discussion

It is imperative that mathematics educators be made aware of the nature and extent of the mathematical and linguistic difficulties faced by their tertiary students. Tertiary students furthermore need assistance when faced with language difficulties when studying university mathematics courses. Research should focus on how to aid second language students in the most effective way possible. Scaffolding of the mathematical language of second language students, should become standard practice. Teachers should use strategies to teach students the language of mathematics and ways to read and interpret word problems [23]. Expecting students to routinely "pick up" the language in class, is to court failure [16]. Teachers need to put in a concerted effort to develop their students' mathematical language and more especially their vocabulary [33].

Also, there is a renewed and growing call for mother tongue instruction, especially in the first four to five years of schooling. Various studies found that increased exposure to mother tongue instruction has positive and significant impacts on income, literacy and numeracy [11] and eventual employment [12].

5. Conclusions

The main findings were that entry-level students enrolled for engineering and science diploma courses struggled to apply fraction arithmetic and that the problems associated with the language of learning and teaching (LoLT) caused difficulties. This study provided important information to school- and university-level mathematics educators by confirming that language difficulties can negatively impact upon the success in learning fractions.

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