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A note on mathematical abilities *vis-à-vis* language of instruction

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This paper describes an investigation into how general attainment of language, comprehension of language with mathematical overtones and interpretation from language to mathematics and vice versa are related to each other.

1. Introduction

The importance of language in the teaching and learning of mathematics can, in the context of a number of investigations, hardly be over-emphasized. Indeed, the wisdom of taking into account the linguistic element can strictly be traced, in recent time, to the Nairobi Symposium [1] followed by the Accra Meet [2]. The 3rd ICME [3] was also seized of it; of course, prior to this one can cite papers by Aiken [4], Lemon [5], Philip [6], etc. Of later references one ought to mention the seminal work of Morris [7], Reed and Waiman [8], Otterburn and Nicholson [9] and of the British activities represented at the Swaziland Seminar [10]. The issue in all these deliberations has been the use of language in conveying mathematical concepts and techniques. This in turn, assumes a complex character if the language of instruction happens to be different from the mother tongue. There are obviously a number of pedagogical issues dependent mainly on attainments and abilities with regard to language in general (whether mother tongue or otherwise) and mathematics, in particular. It then becomes an interesting piece of investigation how general attainment of language (mother tongue or otherwise), comprehension of language with mathematical overtones, and interpretation from language to mathematics and vice versa—are inter-related in the context of the problem posed above. While one can think of modelling these aspects in exclusively theoretical terms, a better insight into such problems can obviously be achieved by resorting to a case study in this direction. The methodology is so geared as to elicit responses on the leading issues mentioned above. The findings of this exercise do bring out the possible inter-relationships between abilities not only in respect of disciplines like mathematics and English, but also of abilities to make use of one for the other. Socio-economic and cultural factors substantially contribute to the overall communication and reception of mathematical content.

2. Motivation

The purpose of the investigation, as already set out, is to look for some kind of reasonably predictive statements resulting from a sample in which the key issue is the interaction between mathematics and the language of communication. A fairly

quantitative form of conclusion seems to be desirable. The sample has been deliberately chosen so as to reflect sociological and psychological facets of this investigation. In brief, the motivation has been to focus on some interfaces between educational aspects of teaching and learning mathematics and their linguistic counterparts.

3. Methodology and description of the sample

In keeping with the objectives of this study one can choose a number of approaches. We have chosen an approach which intrinsically belongs to the group of summative type and hence, a broad-based questionnaire (Appendix 1) addressed to the teachers concerned, has been taken as the guiding tool for the investigation. Though the questionnaire was addressed to the teachers for preparing a reply, constant contact was maintained with them for guiding them in the preparation of the tools for assessing knowledge of the students in any particular desired aspect. Teachers were also interviewed to find out the socio-economic reasons for differences in mathematical achievements.

The sample under consideration consisted of 795 pupils of age group 10+ to 13+ studying in lower secondary classes of schools where the medium of instruction was English which, obviously, was the mother tongue of only a small minority of the pupils (there were, in fact, only 93 pupils whose mother tongue was English). Proper care was taken to ensure that the sample represented a fair cross-section of the society.

The following data were collected from the school records and from the assessment of the pupils by the teachers of mathematics and English over a period of about six months:

- (1) score in English language;
- (2) score in oral English;
- (3) score in English vocabulary with mathematical overtones;
- (4) score in mathematics;
- (5) score in translation from ordinary English to mathematical language and vice versa.

The scores were then arranged columnwise in the order mentioned above and were designated as M_1, M_2, M_3, M_4, M_5 respectively. These five sets of scores were then computerized for the purpose of finding their ranks, square of the difference between two corresponding ranks (D^2) and ultimately finding the coefficients of correlation ($R_{13}, R_{14}, R_{34}, R_{35}, R_{45}$), where R_{xy} means coefficients of correlation between M_x and M_y . While calculating these coefficients of correlation we applied Spearman's rank correlation method. Necessary adjustment for tied ranks in each set of two columns M_x and M_y , was made for higher degree of accuracy in the values of the coefficients of correlation. Probable error (PE) for each R was also calculated to find out whether the value of R was significant. An extract is given in Appendix 2.

The main purpose of calculating the above coefficients of correlation was to find out possible relationships between the corresponding scores with a view to looking into the inter-relations of the following linguistic aspects of mathematical education:

- (1) English language and vocabulary with mathematical overtones;
- (2) English language and mathematics;
- (3) English vocabulary with mathematical overtones and mathematics;

- (4) English vocabulary with mathematical overtones and ability to translate from ordinary English to mathematical language and vice versa;
- (5) mathematics and ability to translate from ordinary English to mathematical language and vice versa.

4. Findings from the sample

Let us now discuss the results obtained from the above analysis. The values of the coefficients of correlation (R_{xy}), the corresponding probable errors (PE_{xy}) and the ratio (R_{xy}/PE_{xy}) are given in the following table.

x, y	R	PE	R/PE
1, 3	0.454	0.019	23.89
1, 4	0.418	0.020	20.80
3, 4	0.586	0.016	36.63
3, 5	0.723	0.011	65.73
4, 5	0.618	0.015	41.20

From the first row we find that although $R_{13} (= 23.89 \times PE_{13})$ is quite significant, it is not so high as to indicate very good relationship between the achievements in English language and in vocabulary with mathematical overtones. From the relation $R_{14} = 20.80 \times PE_{14}$ we find that this coefficient of correlation is quite significant although from the table we find that its value is the lowest of all the coefficients. This means that the observed parity between the achievements in English and mathematics may be due to the general intelligence level of the pupils and the fact that a good knowledge in the language of instruction leads to better understanding in mathematics. Low parity between these achievements may be due to a number of factors, important ones of which appear to be lack of proper knowledge in vocabulary with mathematical overtones and the fact that the medium of instruction is other than the mother tongue. These findings are further strengthened by the results obtained in the third row, where the value of R_{34} and the relation $R_{34} = 36.63 \times PE_{34}$ show that the correlation between the knowledge of vocabulary with mathematical overtones and the achievement in mathematics is quite high and is highly significant. The table further shows that the highest coefficient of correlation is R_{35} and that $R_{35} = 65.73 \times PE_{35}$. From this we may conclude that a good knowledge of the vocabulary with mathematical overtones is extremely important for mathematizing life situations and vice versa. This finding is further confirmed by the values of R_{45} and PE_{45} .

As a part of this exercise 73 teachers at these schools were interviewed. This was done with a view to ascertaining those psychological and socio-economic conditions of the pupils which may be beneficial or detrimental to their mathematical attainments, particularly from the language point of view. The following main points emerged out of this interview:

- (1) Cultural difference between English and the mother tongue of the pupils acts as a barrier to proper comprehension of mathematics.
- (2) The language of instruction being different from the language of common parlance at home and in society, there ought to be an added psychological and

functional difficulty in the proper language comprehension of the pupils which ultimately lowers the level of their mathematical attainments.

- (3) Pupils coming from weaker sections of society and particularly those who are attending school in the first generation, are handicapped because of their language background. This opinion of the teachers was also corroborated by the findings from our sample that out of 93 pupils whose mother tongue was English, as many as 76 could not secure even 40% marks in mathematics, even though their achievement in English was quite high. It was ascertained from the teachers of these pupils that most of them had a poor socio-economic background and were exposed to limited mathematical vocabulary at their homes.

5. Concluding remarks

The above analysis of the sample leads, in a limited way, to some conclusive statements. First, a good knowledge in English language or even in the language of instruction does not necessarily equip a student with an acquaintance in the corresponding vocabulary with mathematical overtones. Indeed, the corresponding coefficient of correlation does not even indicate a flare for this kind of vocabulary. A low parity between these two scores is also discernible, which may be attributed to a variety of factors, one of which may be traced again to lack of knowledge in vocabulary with mathematical overtones. The expression for correlation also reinforces this supposition. Coming to the attainment in vocabulary with mathematical overtones *vis-à-vis* ability in translating from ordinary parlance in English to the language of mathematics, one observes a remarkably high order of parity between the scores; specifically speaking, one is led to the conclusion that a satisfactory attainment in mathematics is assured only when there is a sustained attempt to interweave words with mathematical overtones into the language of instruction. This conclusion is further confirmed by the value of the coefficient of correlation between the scores in mathematics and in the ability to translate from ordinary English to mathematics. This investigation brings to the fore the need to train pupils in the actual process of mathematization through problems, which essentially boils down to translating ordinary common language into the language of mathematics and vice versa. Summing up, the findings indicate in a substantial way that a fairly good acquaintance with the language of instruction does not necessarily endow pupils with the ability to express mathematical terms in written form, much less so in an oral form. A reverse trend also appears, namely, weak attainment in mathematics often accompanies fairly good ability for expression, speech, and use of English, and still more so for pupils in our sample with English as mother tongue.

A necessary adjunct of this investigation may be thought of in the direction of obtaining feed-back from the answer-scripts of a school-leaving examination at the age of 16+ where the language of question and answer was the mother tongue of the candidates. Some marginal comments which have grown out of this exercise may seem pertinent in this context. Essentially, this has enabled us to identify in a limited way some ability levels in certain areas of mathematics rather than the subject as a whole. Some of these findings, from a sample of 546 candidates, are as follows:

- (1) A question on algebra, which needed the formation of an equation from the language of common parlance, was answered by only 42 candidates out of 546. Twenty-five of these 42 failed to form the correct equation because of

lack of knowledge in getting the meaning of the question, or translating this common language to the language of mathematics, or both. This leads us to the conclusion that the candidates were unable to translate ordinary language into the language of mathematics which, in terms of the result of our original investigation, show that they were very weak in their knowledge of vocabulary with mathematical overtones even though it was their mother tongue.

- (2) In the case of another question on geometry, 306 candidates out of 546 attempted to answer the question. One hundred and twenty six of these 306 candidates could not even translate the problem from the language of the question paper to the language of geometry, i.e., they could not even draw the correct geometrical figure. From this again it may be concluded that their knowledge of vocabulary with overtones in geometrical language was poor.

The above investigations have obviously some limitations; for example, the socio-economic backgrounds affecting linguistic abilities and the cultural aspect have not been fully assessed, although, as mentioned earlier, feed-back from practising teachers provides some revealing information about this to the extent that pupils belonging to the weaker sections of society are, by and large, handicapped by lack of the vocabulary which often facilitates mathematization. It is expected that a detailed investigation into this aspect may provide us with information, hitherto unknown, which may ultimately lead to better mathematical education.

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Appendix 1

(An extract from the questionnaire to the teachers.)

You are requested kindly to supply information about your pupils in the following table. Please note that the particulars are required for pupils of classes 5, 6, 7 and 8. In respect of columns 6, 7 and 9, as discussed, the scores may please be obtained from at least five different tests and their average is taken as the final score. Scores are to be given in terms of percentage marks.

Column 1. Serial No.

Column 2. Name of pupil.

- Column 3.* Boy(B) or Girl(G), Day Scholar(D) or Boarder(B). Please write: BD, BB, GD, GB as the case may be.
- Column 4.* Mother tongue—English(E) or any other language(N). Please write: E or N as the case may be.
- Column 5.* Knowledge of English language. Please give the results of the Annual Examination of 1979. Had there been no formal examination please give average result on record for each pupil.
- Column 6.* Knowledge of spoken English. Please give the average of not less than five tests as discussed.
- Column 7.* Here is a list (not exhaustive) of English words with mathematical overtones. Please pick up the words and any other word of this nature suitable for your class and mark each pupil according to his knowledge in those words. For the purpose of this test please frame questions as discussed and take the average of at least five tests.

List of words:

Length, distance, time, area, volume, shape, term, order, ascending, descending, natural, rational, interest, compound, simple, constant, variable, relation, function, concurrent, even, odd, factor, set, discount, origin, simultaneous, intersection.

- Column 8.* Attainment in mathematics. Please give the results of the Annual Examination of 1979. Had there been no formal annual examination please give the average result on record for each pupil.
- Column 9.* Capability of interpreting from ordinary English language to mathematics and vice versa. Please give average of at least five tests as discussed.
- Remarks:* At the end of the list please state any specific problems, including those arising out of the psychological and socio-economic background of the pupils, faced by you and your pupils in teaching and learning mathematics through the medium of English.

Appendix 2

Rank determination and correlation table (sample of 25 pupils).

No.	M_1	$R(M_1)$	M_2	$R(M_2)$	M_3	$R(M_3)$	M_4	$R(M_4)$	M_5	$R(M_5)$	D_{13}^2	D_{14}^2	D_{34}^2	D_{35}^2	D_{45}^2
1	54.00	289.50	69.00	190.00	50.00	428.50	34.00	540.00	30.00	661.00	19321.00	62750.25	12432.25	54056.25	14641.00
2	51.00	358.50	70.00	177.00	50.00	428.50	65.00	183.50	70.00	182.50	4900.00	30625.00	60025.00	60516.00	1.00
3	61.00	177.00	70.00	177.00	50.00	428.50	48.00	341.00	50.00	441.00	63252.25	27060.25	7569.00	156.25	9900.25
4	33.00	696.00	30.00	749.50	30.00	677.50	52.00	306.50	45.00	478.50	342.25	151710.25	137641.00	39601.00	29584.00
5	53.00	309.00	52.00	491.00	38.00	629.00	68.00	157.50	58.00	376.50	102400.00	22952.25	222312.25	63756.25	47961.00
6	41.00	571.00	45.00	579.50	39.00	591.00	24.00	628.50	13.00	752.00	400.00	3306.25	1406.25	25921.00	75252.25
7	62.00	160.00	75.00	143.50	57.00	367.50	71.00	127.00	73.00	159.50	43056.25	1089.00	57840.25	43264.00	1056.25
8	54.00	289.50	61.00	286.00	60.00	279.00	23.00	639.50	60.00	298.00	110.25	122500.00	129960.25	361.00	116622.25
9	61.00	177.00	68.00	203.50	48.00	459.50	22.00	653.50	19.00	732.50	79806.25	227052.25	37636.00	74529.00	6241.00
10	58.00	288.50	61.00	286.00	40.00	546.50	12.00	740.00	18.00	752.00	101124.00	261632.25	37442.25	42230.25	144.00
11	40.00	608.00	45.00	579.50	30.00	677.50	43.00	407.00	35.00	648.00	4830.25	40401.00	73170.25	870.25	58081.00
12	40.00	608.00	42.00	614.50	32.00	671.00	16.00	707.50	17.00	763.50	3969.00	9900.25	1332.25	8556.25	316.00
13	84.00	18.00	85.00	25.50	75.00	135.00	84.00	56.00	78.00	117.00	13689.00	1444.00	6241.00	324.00	3721.00
14	47.00	408.50	61.00	286.00	60.00	279.00	42.00	420.50	35.00	648.00	16770.25	144.00	20022.25	136161.00	51756.25
15	65.00	125.00	72.00	164.00	60.00	279.00	40.00	476.00	38.00	616.00	23716.00	123201.00	38809.00	113569.00	19600.00
16	61.00	177.00	55.00	456.00	40.00	546.50	40.00	476.00	38.00	616.00	136530.25	89401.00	4970.25	4830.25	19600.00
17	55.00	274.50	65.00	238.00	56.00	385.00	41.00	435.00	38.00	616.00	12210.25	25760.25	2500.00	53361.00	32761.00
18	53.00	309.00	52.00	491.00	39.00	591.00	4.00	791.50	10.00	786.50	79524.00	232806.25	40200.25	33220.25	25.00
19	87.00	9.00	90.00	7.50	75.00	135.00	84.00	56.00	79.00	101.00	15876.00	2209.00	6241.00	1156.00	2025.00
20	40.00	608.00	43.00	603.50	15.00	780.00	17.00	700.50	17.00	763.00	29584.00	8556.25	6320.25	272.25	3969.00
21	63.00	146.00	80.00	77.00	60.00	279.00	18.00	691.50	20.00	711.50	17689.00	297570.25	170156.25	187056.25	400.00
22	50.00	383.50	52.00	491.00	45.00	483.50	51.00	315.50	55.00	408.50	10000.00	4624.00	23224.00	5625.00	8649.00
23	62.00	160.00	80.00	77.00	48.00	459.50	24.00	628.50	60.00	298.00	89700.25	219492.25	26561.00	26082.25	109230.25
24	73.00	63.00	75.00	143.00	50.00	428.00	41.00	435.00	45.00	478.50	133590.25	138384.00	42.25	2500.00	1892.95
25	85.00	22.00	85.00	25.50	56.00	385.00	40.00	476.00	43.00	492.50	131769.00	206116.00	8281.00	21556.25	272.25

Mathematical abilities vis-à-vis language of instruction

$R_{xy} = 1 - \frac{6\sum D_{xy}^2 + \frac{1}{12}\sum(t_x^3 - t_x) + \frac{1}{12}\sum(t_y^3 - t_y)}{n(n^2 - 1)}$, where t_x stands for the number of times a particular rank is repeated in column M_x and t_y stands for the same in column M_y .

$$PE_{xy} = 0.6745 \frac{1 - R_{xy}^2}{\sqrt{n}}$$