ANALYSIS OF GENDER DIFFERENCES IN EDUCATION FOR ENGINEERING CAREER (GABORONE CASE STUDY)

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The percentage of students, especially women in engineering, is very low in Botswana and the country is still heavily dependent upon foreign human resources. The objective of this research has been to study the gender differences in education, which might have caused the current poor representation of women in engineering. The secondary school results of 749 students were statistically analyzed per gender. Three main factors were identified by Factor analysis: the science- ability, the general- aptitude and the memory-ability factor. As to the general-aptitude and memory-ability, it was found that no statistically significant difference between boys and girls exists. However, there is a difference in the science-ability factor. To strengthen this factor for girls, it requires to make the studies of Mathematics and Science courses attractive to girls at early stage so that they are not limited in their options at the level of secondary education and thus in their career choice.

1 INTRODUCTION

Botswana has undergone a remarkable economic growth in recent years. This transformation has contributed to significant social development [1]. Compared to developing countries worldwide, the Botswana government has invested quite heavily in resources for science and technology education at all levels. However, the percentage of students, especially women in engineering, is very low and the country is still heavily dependent on foreign human resources.

The global economy of today and the rising awareness of the role of technology in the competitive positioning of companies and countries have created an anxiety about Botswana technical workforce [2]. This, in turn, has caused an examination of school system and its ability to attract students into mathematics and science programs.

The Revised National Policy on Education, approved by Parliament in 1994, is the result of an extensive consultation process carried out by the National Commission on Education in 1993. This new policy places substantial emphasis on science and technology education, as well as on technical and vocational education.

To have the necessary technologically literate human resources ready for the 21[st] century, it is essential to make science, technology and engineering attractive to girls as well as to boys. The efforts will definitely contribute to the strengthening in the science and technology education.

Although all educational institutions and all courses are open to both female and male students and there is not obvious discrimination in admission procedures, the participation of women in science and technology courses becomes low as soon as the subjects become optional. A recent study carried out indicates that the cause for this situation is mainly social and attitudinal.

2 THE OBJECTIVE OF THE STUDY

The objective of the study was to understand the barriers and inhibitions, which have caused the current underrepresentation of women in science and engineering, and to analyze factors, which might determine the option of further field of study at University level.

The hypothesis has been formulated that the choice of further field of specialization/professional career depends upon the performance and level of knowledge attained in the secondary school subjects.

3 THE SURVEY SAMPLE

The results from the performance of 749 students (363 boys and 386 girls) from three Senior Secondary schools in Gaborone (form 4 and 5, year 1996/97) had been collected. The selection of schools and classes was random. About 2000-3000 students sit for the same examination each year in Gaborone governmental schools. The marks of girls and boys in each subject were statistically analyzed. The results are presented in Tables 1 to 5.

4 BASIC FINDINGS

Table 1 contains basic statistics for a comparison per gender. For each subject the mean marks (which students achieved at their final examinations) and standard deviations have been calculated for both sex groups. The t-test has been used for a comparison of performance of boys and girls in each subject. The normality assumptions for application of t-test have been verified by testing the skewness and the kurtosis of the sample distribution [3]. It was found that there are no significant differences from normality at 5 % significant level in the data sets of the size smaller than 100. In data sets of the size bigger than 100 there were some significant differences but use of the t-test in this case can be justified by central limit theorem.

The version of t –test (with pooled variance estimate or separate variance estimate) has been chosen on the base of F-test results [4]. The two-tail probabilities corresponding to t-statistics are presented in Table 1. In this table * or ** notes a significant difference at 5 % or 1 % significance level, respectively.

The conclusion can be drawn from the results as follows:

4.1 Girls are achieving better results at 1 % level of significance in Setswana language;

4.2 Boys have performed better particularly in mathematics, physics and generally in all natural sciences (significant difference at 1% level);

4.3 However, for girls who have opted for advanced mathematics course, their performance is not significantly different from those of boys. The total number of students who took this course has been relatively low but it might reflect well the proportion of students going for University studies in science and engineering. The girls who have done the advance mathematics course have achieved results which were not significantly different from those of boys and have the good background knowledge to follow career in the field of science and engineering. The Department of Civil Engineering record of students results shows that girls results are at par or even better than those of their male counterparts. In 1997 the best student of FET was a girl and also in the group of the first graduands in 1995 a girl was the first class student.

Table 2 presents the comparison of 95 % confidence intervals for mean marks in all subjects per gender. The results confirm the conclusion derived from Table 1 that while girls are generally better in languages, boys are achieving significantly better results in mathematics and natural sciences (Fig.1). The confidence intervals reflect the variability of results in considered subjects and show how boys and girls mean marks in different subjects overlap.

No	Subject	No of cases			Mean			St.Deviation			F-test 2 Tail Prob.	T-test 2 Tail Prob.
		Boys	Girls	Tot.	Boys	Girls	Total	Boys	Girls	Total		
1	English	363	385	748	57.0303	58.6338	57.8556	13.8419	14.0072	13.9410	0.820	0.116
2	Engl.Lit.	23	41	64	53.8261	61.3415	58.6406	16.8675	16.9744	17.1902	1.000	0.094
3	French	40	64	104	51.9250	51.2031	51.4808	19.0860	22.0894	20.8927	0.330	0.865
4	Setswana	225	243	468	49.7644	55.5926	52.7906	12.0724	11.0601	11.9077	0.181	0.000**
5	Maths	363	385	748	50.9752	42.8234	46.7794	23.3949	23.2620	23.6648	0.912	0.000**
6	Adv.Maths	43	26	69	62.9767	56.7308	60.6232	20.1287	25.2516	22.2255	0.190	0.261
7	Biology	207	189	396	58.9662	53.6825	56.4444	16.8256	17.0670	17.1248	0.840	0.002**
8	Physics	123	78	201	56.1301	48.9487	53.3433	11.5659	12.2049	12.2986	0.590	0.000**
9	Chemistry	141	90	231	64.1560	56.9444	61.3463	13.3407	14.2359	14.1129	0.488	0.000**
10	Phys.science	143	197	340	48.3706	43.8122	45.7294	16.4431	15.8304	16.2242	0.620	0.010**

Table 1 Means and Standard deviations of the marks for both sex groups, F- and T-tests.

No	Subject	Mean		95 % Confidential Intervals for means	
		Boys	Girls	Boys	Girls
1	English	57.0303	58.6338	55.6016 to 58.4590	57.2302 to 60.0374
2	Engl.Lit.	53.8261	61.3415	46.5320 to 61.1202	55.9837 to 66.6992
3	French	51.9250	51.2031	45.8210 to 58.0290	45.6854 to 56.7209
4	Setswana	49.7644	55.5926	48.1784 to 51.3504	54.1954 to 56.9902
5	Maths	50.9752	42.8234	48.5605 to 53.3899	40.4924 to 45.1543
6	Adv.Maths	62.9767	56.7308	56.7820 to 69.1715	46.5314 to 66.9301
7	Biology	58.9662	53.6825	56.6605 to 61.2718	51.2336 to 56.1315
8	Physics	56.1301	48.9487	54.0656 to 58.1945	46.1969 to 51.7005
9	Chemistry	64.1560	56.9444	61.9348 to 66.3772	53.9628 to 59.9261
10	Phys.science	48.3706	43.8122	45.6524 to 51.0888	41.5879 to 46.0365
11	Ave	54.3802	51.9404	53.1205 to 55.6398	50.7398 to 53.1410

Table 2 95% Confidence Intervals for Means

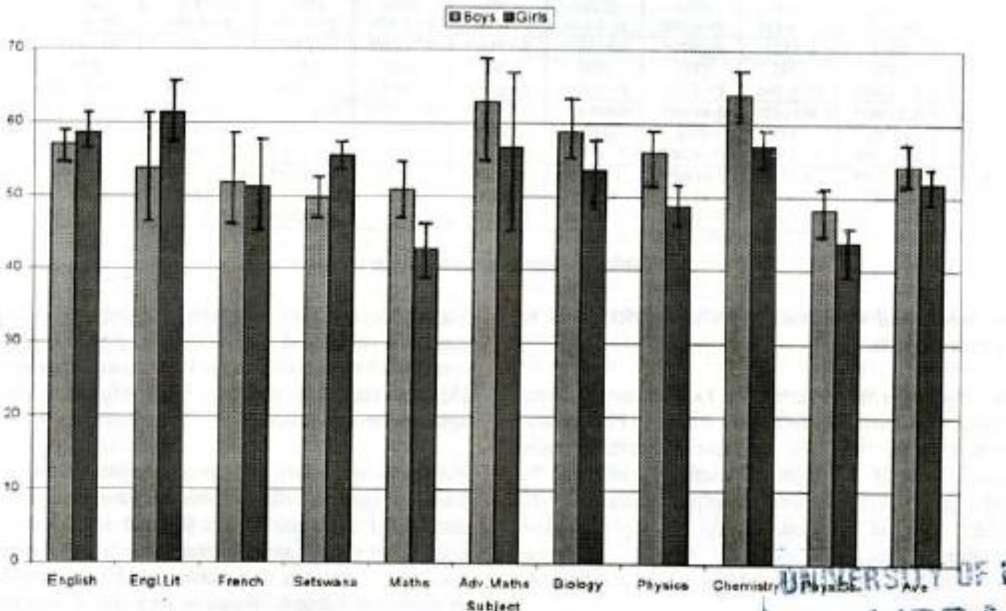

Fig.1 Mean marks and 95% confidence intervals for means per gender (marked by I)

The previous statistical analysis does not reflect correlation between performances in different subjects. That is why the multivariate statistical analysis approach has been used for comparison of boys and girls performance, which respects the correlation structure of results in different subjects.

The results of correlation analysis are given in the Table 3. The pairwise method for dropping the cases with missing values has been used for calculation of correlation coefficients. Thus, three values for each pair of subjects are presented in the table. They are: Pearson correlation coefficient, and then in parenthesis – number of pairs without at least one value missing and 2 – tailed probability P for testing statistical association between corresponding subjects. The symbol * or ** stands by correlation coefficient if the correlation between corresponding subjects is statistically significant at 5 % or 1 % significant level, respectively. The number of pairs in parentheses has been printed only if the number of pairs was small and the coefficient could not be calculated or test could not be performed. Because the correlation between subjects in many cases is high enough, a factor analysis has been used [7] to describe the general factors, which can

Subject	English	Engl.Lit.	French	Setswana	Maths	Adv.Mat.	Biology	Physics	Chemistry	Phys.Sc.
English	1.0000 (748) P =0.000	0.3477** (63) P= 0.005	0.3142** (104) P= 0.001	0.3633** (467) P= .000	0.4886** (746) P= 0.000	0.0750** (69) P= 0.540	0.4253** (395) P= 0.000	0.3061** (200) P= 0.000	0.2544** (230) P= 0.000	0.5173** (340) P= 0.000
Engl.Lit.	0.3477** (63) P= 0.005	1.0000 (64) P= 0.000	0.7166** (16) P= 0.002	-0.0930 (13) P=0 .763	0.3189* (63) P= 0.011	(0)	-0.0823 (37) P= 0.628	0.1822 (24) P= 0.394	0.3677 (19) P= 0.121	-0.1719 (4) P= 0.828
French	0.3142** (104) P= 0.001	0.7166** (16) P= 0.002	1.0000 (104) P= 0.000	(0)	0.3857** (103) P= 0.000	0.0190 (11) P= 0.956	0.4815** (66) P= 0.000	0.3975* (33) P= 0.022	0.4897** (36) P= 0.002	0.6100** (19) P= 0.006
Setswana	0.3633** (467) P= 0.000	-0.0930 (13) P= 0.763	(0)	1.0000 (468) P= 0.000	0.4130** (467) P= 0.000	0.3975* (39) P= 0.012	0.4203** (230) P= 0.000	0.3106** (93) P= 0.002	0.3788** (122) P= 0.000	0.3542** (286) P=0.000
Maths	0.4886** (746) P=0.000	0.3189* (63) P= 0.011	0.3857** (103) P= 0.000	0.4130** (467) P= 0.000	1.0000 (748) P= 0.000	0.7706** (69) P= 0.000	0.6102** (395) P= 0.000	0.5789** (201) P= 0.000	0.6911** (231) P= 0.000	0.7400** (339) P= 0.000
Adv.Maths	0.0750 (69) P= 0.540	(0)	0.0190 (11) P= 0.956	0.3975* (39) P= 0.012	0.7706** (69) P=0.000	1.0000 (69) P= 0.000	0.4586** (66) P= 0.000	0.7022** (60) P= 0.000	0.6021** (66) P= 0.000	(2)
Biology	0.4253** (395) P= 0.000	-0.0823 (37) P= 0.628	0.4815** (66) P= 0.000	0.4203** (230) P= 0.000	0.6102** (395) P= 0.000	0.4586** (66) P= 0.000	1.0000 (396) P= 0.000	0.4676** (181) P= 0.000	0.5013** (215) P= 0.000	0.6992** (101) P= 0.000
Physics	0.3061** (200) P= 0.000	0.1822 (24) P= 0.394	0.3975* (33) P= 0.022	0.3106** (93) P= 0.002	0.5789** (201) P= 0.000	0.7022** (60) P= 0.000	0.4676** (181) P= 0.000	1.0000 (201) P= 0.000	0.6681** (185) P= 0.000	(0)
Chemistry	0.2544** (230) P= 0.000	0.3677 (19) P= 0.121	0.4879** (36) P= 0.002	0.3788** (122) P= 0.000	0.6911** (231) P= 0.000	0.6021** (66) P= 0.000	0.5013** (215) P= 0.000	0.6681** (185) P= 0.000	1.0000 (231) P= 0.000	(0)
Phys.Sc.	0.5173** (340) P= 0.000	-0.1719 (4) P= 0.828	0.6100** (19) P= 0.006	0.3542** (286) P= 0.000	0.7400** (339) P= 0.000	(2)	0.6992** (101) P= 0.000	(0)	(0)	1.0000 (340) P= 0.000

Table 3 Results of correlation analysis

have substantial influence on student performance in different subjects.

The subjects, which entered the factor analysis, were English, Setswana, Mathematics, Biology, Physics and Chemistry. It was not possible to involve more subjects even if it might be useful because in the sample there were only small numbers of students who studied pairs of subjects, as for example English Literature - Physics (4 students), French - Setswana (no students), Physics - Physical Sciences (no students).

To find out if sample correlations between chosen subjects are high enough for effective factorization, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy has been calculated. Its value was 0.81433, which is considered to be meritorious for further factor analysis [5] and this way the possibility of factor analysis application is justified.

For factor extraction the principal component method has been used. It follows from the basic criterion for a number of extracted factors [6] that for 6 subjects at least three factors are necessary to extract. The results for factor analysis for three extracted factors are presented in Table 4. It can be seen that a contribution of these three factors to the total sample variance is 81.3 %, which is satisfactory and high enough too. Thus, the three extracted factors communalities

Variable	Communality	Factor	Eigenvalue	Pct of Var	Cum Pct
English	0.92102	1	3.33552	55.6	55.6
Setswana	0.98261	2	0.88795	14.8	70.4
Maths	0.77540	3	0.65627	10.9	81.3
Biology	0.61509				
Physics	0.75089				
Chemistry	0.83472				

Table 4 Final statistics of factor analysis

(the portions of variance of each subject contributed by three extracted common factors) are high enough too. Thus, the three extracted factors give useful statistical model for explanation of student performances even if 18.7% of variability of marks remain unexplained. But this is usual factor analysis' disadvantage.

For better interpretation the factors were orthogonally rotated by varimax method. The matrix of factor loading, obtained this way, is presented in the Table 5. It is clear from the table, that the first factor has the highest loading in science subjects and that is why it was called science-ability factor.

Variable	Factor 1	Factor 2	Factor 3
English	0.12979	0.94005	0.14312
Setswana	0.19879	0.18474	0.95340
Maths	0.73043	0.45033	0.19769
Biology	0.54244	0.47479	0.30891
Physics	0.85319	0.13321	0.07225
Chemistry	0.88749	0.05749	0.20928

Table 5 Rotated factor loading matrix

The second factor has the highest loading in English, Biology and Mathematics, which means that this factor reflects general ability of students and we can call it general-aptitude factor. The third factor has the highest loading in Setswana and Biology, therefore it is called memory-ability factor.

After extracting rotating factors the regression factor scores of each student were calculated and the boys and girls have been compared by t-test again to find out what are the differences in these three factors between boys and girls. The results were as follows: For science-ability factor (factor 1) it was found by F-test that there are no differences in variability between boys and girls ($F(50,38) = 1.20$, $P = 0.562 > 0.05$) but the difference in mean level of this factor was found statistically highly significant at 1% significant level by t-test ($t(87)=3.48$, $P=0.001<0.01$).

For general-aptitude factor (factor 2) and memory-ability factor (factor 3) there were no differences at significance level 1% and 5% between boys and girls neither in variability ($F(50,38)=1.19$, $P=0.585>0.05$) for factor 2 and ($F(50,38) = 1.129$, $P=0.416>0.05$) for factor 3 nor in means of the factors ($t(87)= -0.16$, $P=0.87>0.05$) for factor 2 and ($t(87)= -1.46$, $P=0.148>0.05$) for factor 3.

Hence, the performed analysis shows that the main differences between boys and girls (form 4 and 5) are explained by the difference in science-ability factor. To achieve the strengthening of this factor for girls, it requires to make the studies of Mathematics and Science courses attractive to the girls at early stage so that they are not limited in their options at the level of secondary education and thus in their career choice.

5 COMPARISSON WITH OTHER COUNTRIES

Is the problem of low participation of women in engineering unique to Botswana?

To answer this question, a literature survey was conducted. It came out clearly, that the same problem occurs in developed as well as in developing countries. The importance of attracting girls into engineering profession has been recognized worldwide.

The research findings and strategies adopted are summarized as follows:

5.1 UK

To change the still unbalanced ratio of men and women entering higher education in Engineering and Technology, several projects and strategies were adopted. One of the most popular projects is the WISE campaign (Women in Science and Engineering). The scheme was launched in 1982 to change the attitude of young people, parents, teachers and the general public about the suitability of engineering as a career for girls. The campaign has been wide ranging including publications, posters, and career advisory services. However one of the most innovative parts of the campaign was the setting up of the first WISE bus as a mobile teaching/exhibition centre. Groups of 14-15 year schoolgirls spend time on the bus when it visits their school with women tutors, providing hands on experience of new technologies. The programme has been a huge success. The running and equipping of the buses have been achieved through sponsorship by industry in the UK.

Another pilot scheme with WISE was completed in 1996 to promote a three day pilot scheme for 12-13 year old girls to participate in an engineering activity programme as a taster prior to choosing their curriculum subjects for study at GCSE level [8].

5.2 Canada

In the past decade a notable increase in participation of women in engineering has occurred. The national average enrolment of women in undergraduate and graduate programmes has increased from around 12% in 1988 to just 20% in 1995.

What has contributed to this change?

A national Chair in Women in engineering has been created at the University of New Brunswick, in 1989, financially supported by a large corporation (Nortel) and the Natural Sciences and Engineering Research Council. The mandate of the chair is to encourage an increase in the participation of women in the engineering profession, at all levels and across the country.

The conducted studies indicated that the social barriers which limit the participation of young women in non-traditional education programmes start as early as birth and continue at all levels of the education system. They perpetuate the myth that the physical sciences, mathematics and engineering are fields of study for men. Thus, by the graduation year in high school, a small number of women are left in the pool of candidates qualified to enter into an Engineering Programme.

Strategies adopted for change have been to organize workshops for parents and career counselors, textbooks portraying women and men in active and sharing roles. Videos have been created on careers in Engineering and careers in Science, showing how engineers and scientists apply their knowledge to the benefit of humankind. A non-traditional career day at a junior and senior high schools has been organized by various universities and colleges in Canada [9].

5.3 Switzerland

The recent survey has revealed that the proportion of women in technical profession is still very low. The percentage of graduated women engineers is stagnant at about 4%. The Swiss Association of Women Engineers was founded in 1991. The main objective of this association is to increase the attraction of engineering, as a whole, to women. Studies undertaken by this association revealed that to make the engineering profession attractive to women, it requires to give more attention to the age group of 9-13.

Efforts to address low enrolment of women in subject as engineering often target women between the ages of 16 and 18. It is felt that programmes aimed at these women may add to the numbers in engineering at the expense of the science subjects, which also suffer from low female enrolment. To increase the number of women in technologically based programmes, a gender barrier that affects girls in their early schools years must be removed [10].

5.4 France

Although women were accepted for the first time in an engineering school in 1917, their numbers are still significantly lower than in other fields. The reasons were found at the secondary schools, where prejudices deterring girls from the technical sections are still strong. Although girls prove to be more successful at school at an early stage, only slightly more than 30% attend the C-section leading to a Maths and Physics baccalaurea. As a consequence, percentage of female students following a technological curriculum after the baccalaureat has stabilized around 30%. Informing and attracting girls towards the engineering profession at an early stage in secondary schools was adopted as a strategy how to increase their number [11].

5.5 India

A survey conducted in some Indian Universities has shown the following admission pattern in the year 1990-91: 20% in Electronics, 15% in Electrical Engineering, 4% in Civil Engineering and 0% in Mechanical Engineering.

The parents and often college authorities dissuade women to join these courses and even sometimes just debar women's admission. There is also employment problem for women after graduation in these courses.

The study recommended the following strategy:

- Educational counseling and career guidance should start at the primary and secondary level.
- Girls have to be encouraged to take Maths and Science subjects in Higher Secondary education.
- Better information to girls regarding employment opportunities in Engineering has to be provided.
- Exposure to various science and technical activities through formal and non-formal course should be provided [12].

5.6 Zimbabwe

Very few women are engaged in engineering in Zimbabwe due to educational restraints, traditional and cultural pressures, absence of role models and lack of career information.

Often the information about tertiary education entry requirements is given too late for the pupils to choose the right combination of subjects. The recommended future action to encourage women to take their place in engineering world includes to portray women as well as men in printed material and other visual aids for career guidance.

It has been recommended to ensure that the engineering career advisory teams include women members whenever possible. Affirmative action can also play an important role in the process of changing public opinion. Also, with government being the main sponsor of students there is a hope that more women will obtain sponsorship for engineering studies [13].

5.7 Kenya

Kenya has seen a steady increase in number of primary and high schools, colleges and universities. Within the last decades, girls constitute almost 50% of the enrolment in schools. In spite of this trend an insignificant number opts for the engineering faculties. Authors reemphasized that the choice to enroll in the faculty starts with the selection of Mathematics, Physics and Chemistry at school level. From a sample of schools it was noted that compared to boys schools a relatively smaller number of girls school offered the combination leading to entry requirements. Recommendations for change in this respect were made [14].

5.8 Ghana

In recent years, special efforts have been made by the educational authorities in Ghana to address the imbalance of girls to boys ratio in Science.
There is a myth that boys perform better at Mathematics and Science than girls.

The results presented in [15] show that at O'level girls form only 11.9% of students who sat for Advanced Mathematics, 10.9% for Physics and 12.8% for Chemistry, i.e. for courses which are the pre-requisite for engineering studies.
However, the study on the examination results of three categories of schools (A - single-girls' schools, B – single-boys' schools, C - mixed school) seems to indicate that girls' performance in Mathematics (if they opt for it) is par with that of boys.

The Ghana Education Service and the Association of Women in Science and Technology in Ghana are reaching out to secondary school girls through programmes of Science clinics and career guidance on regional, district and local levels in order to reach as many schoolgirls as possible.

6 CONCLUSIONS

The above observations and findings lead to the general conclusion that the problem of attraction of more girls in schools towards engineering and scientific careers deserves a serious attention and starts at an early stage in secondary schools. Numerous women engineers in various sectors of activity can be used as role models for this purpose. The successful involvement of women in engineering has nowadays clearly abolished the outdated argument that technical subjects are not suitable for women.

It is essential that girls are encouraged to study Mathematics and Science in schools and that teachers are made aware of the career opportunities of their students in industry. It is needed to ensure that Science and Mathematics are being taught in interesting, challenging styles which both girls and boys can find stimulating. The role that teachers play in influencing young minds is very significant and ensuring they know what industry has to offer young people in career opportunities is paramount.

Over the past few years a great deal has happened for the good in education: new technologies have been introduced, computers are more common, and equal opportunities polices are progressing in schools. Nevertheless the need for girls to be technologically competent is an urgent one. It is difficult for a youngster still at school to imagine what a profession of engineering is like. If local industry can send young women involved in interesting jobs to talk to the girls that is very worthwhile. The role female model can talk about reality of their jobs and encourage girls to realize that they too could be knowledgeable and take on responsibilities in their work. They could encourage them to see that their school works in science and technology can be of immense value in the development of lifelong rewarding career.

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