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

Mrs. S. Nair, Dr. V. Vokolkova, Dr. T. Abadjieva
Department of Civil Engineering
Faculty of Engineering and Technology
University of Botswana, Gaborone

Dr. J. Michalek
Department of Mathematics
Faculty of Science
University of Botswana, Gaborone

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 21st 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 advanced 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 is the group of the first graduates 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.

<table>
<thead>
<tr>
<th>No</th>
<th>Subject</th>
<th>No of cases</th>
<th>Mean</th>
<th>St.Deviation</th>
<th>F-test 2 Tail Prob</th>
<th>T-test 2 Tail Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Total</td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>1</td>
<td>English</td>
<td>365</td>
<td>385</td>
<td>748</td>
<td>57.8303</td>
<td>58.6338</td>
</tr>
<tr>
<td>2</td>
<td>Eng.Lit.</td>
<td>22</td>
<td>41</td>
<td>64</td>
<td>53.3261</td>
<td>61.3415</td>
</tr>
<tr>
<td>3</td>
<td>French</td>
<td>40</td>
<td>64</td>
<td>104</td>
<td>51.9250</td>
<td>51.2031</td>
</tr>
<tr>
<td>4</td>
<td>Setswana</td>
<td>225</td>
<td>243</td>
<td>468</td>
<td>49.764</td>
<td>55.5926</td>
</tr>
<tr>
<td>5</td>
<td>Maths</td>
<td>365</td>
<td>385</td>
<td>748</td>
<td>50.7572</td>
<td>42.8234</td>
</tr>
<tr>
<td>6</td>
<td>Adv.Maths</td>
<td>43</td>
<td>26</td>
<td>69</td>
<td>62.5767</td>
<td>56.7308</td>
</tr>
<tr>
<td>7</td>
<td>Biology</td>
<td>207</td>
<td>189</td>
<td>396</td>
<td>58.9662</td>
<td>53.8283</td>
</tr>
<tr>
<td>8</td>
<td>Physics</td>
<td>123</td>
<td>78</td>
<td>201</td>
<td>56.1501</td>
<td>48.9487</td>
</tr>
<tr>
<td>9</td>
<td>Chemistry</td>
<td>141</td>
<td>90</td>
<td>231</td>
<td>64.1560</td>
<td>66.9444</td>
</tr>
<tr>
<td>10</td>
<td>Phys.science</td>
<td>143</td>
<td>197</td>
<td>340</td>
<td>48.3766</td>
<td>43.8122</td>
</tr>
</tbody>
</table>

Table 1 Means and Standard deviations of the marks for both sex groups, F- and T-tests.
Table 2 95% Confidence Intervals for Means

<table>
<thead>
<tr>
<th>No</th>
<th>Subject</th>
<th>Mean Boys</th>
<th>Mean Girls</th>
<th>95% Confidence Intervals for means Boys</th>
<th>95% Confidence Intervals for means Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>English</td>
<td>57.0307</td>
<td>58.6338</td>
<td>55.6016 to 58.4590</td>
<td>57.2302 to 60.0374</td>
</tr>
<tr>
<td>2</td>
<td>Engl. Lit.</td>
<td>53.8261</td>
<td>61.3415</td>
<td>46.5320 to 61.1202</td>
<td>55.9837 to 66.6992</td>
</tr>
<tr>
<td>3</td>
<td>French</td>
<td>51.9250</td>
<td>51.2031</td>
<td>45.8210 to 58.0290</td>
<td>45.6854 to 56.7209</td>
</tr>
<tr>
<td>4</td>
<td>Setswana</td>
<td>49.7644</td>
<td>55.9268</td>
<td>48.1784 to 51.3504</td>
<td>54.1954 to 56.9902</td>
</tr>
<tr>
<td>5</td>
<td>Maths</td>
<td>50.9752</td>
<td>42.8234</td>
<td>48.5605 to 53.3899</td>
<td>40.4924 to 45.1543</td>
</tr>
<tr>
<td>6</td>
<td>Adv. Maths</td>
<td>62.9767</td>
<td>36.7308</td>
<td>56.7820 to 69.1715</td>
<td>46.5314 to 66.9301</td>
</tr>
<tr>
<td>7</td>
<td>Biology</td>
<td>58.9662</td>
<td>53.5825</td>
<td>56.6605 to 61.2718</td>
<td>51.2336 to 56.1215</td>
</tr>
<tr>
<td>8</td>
<td>Physics</td>
<td>56.1301</td>
<td>48.9487</td>
<td>54.0656 to 58.1945</td>
<td>46.1969 to 51.7605</td>
</tr>
<tr>
<td>9</td>
<td>Chemistry</td>
<td>64.1560</td>
<td>56.9444</td>
<td>61.9348 to 66.3772</td>
<td>53.9628 to 59.9261</td>
</tr>
<tr>
<td>10</td>
<td>Phys. scie.</td>
<td>48.3706</td>
<td>43.8122</td>
<td>45.6524 to 51.0888</td>
<td>41.5879 to 46.0365</td>
</tr>
<tr>
<td>11</td>
<td>Ave</td>
<td>54.3802</td>
<td>51.3404</td>
<td>53.1205 to 55.6398</td>
<td>50.7398 to 53.1410</td>
</tr>
</tbody>
</table>

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

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
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 criteria 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

\[
\begin{array}{ccccccc}
\text{Variable} & \text{Communality} & \text{Factor} & \text{Eigenvalue} & \text{Pct of Var} & \text{Cum Pct} \\
\text{English} & 0.92102 & 1 & 3.33552 & 55.6 & 55.6 \\
\text{Setswana} & 0.98261 & 2 & 0.88795 & 14.8 & 70.4 \\
\text{Maths} & 0.77540 & 3 & 0.65627 & 10.9 & 81.3 \\
\text{Biology} & 0.61509 & & & & \\
\text{Physics} & 0.75089 & & & & \\
\text{Chemistry} & 0.83472 & & & & \\
\end{array}
\]

Table 3 Results of correlation analysis

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.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>0.12979</td>
<td>0.94005</td>
<td>0.14312</td>
</tr>
<tr>
<td>Setswana</td>
<td>0.19879</td>
<td>0.18474</td>
<td>0.09530</td>
</tr>
<tr>
<td>Maths</td>
<td>0.73043</td>
<td>0.45033</td>
<td>0.19769</td>
</tr>
<tr>
<td>Biology</td>
<td>0.54244</td>
<td>0.47479</td>
<td>0.30891</td>
</tr>
<tr>
<td>Physics</td>
<td>0.85319</td>
<td>0.13321</td>
<td>0.07225</td>
</tr>
<tr>
<td>Chemistry</td>
<td>0.88749</td>
<td>0.05749</td>
<td>0.20928</td>
</tr>
</tbody>
</table>

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 COMPARISON 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 tool 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
detering 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 enrollment 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.

REFERENCES


15. Andam A.B., Essel P., Yebuah C., Science Education in Ghana, Ninth International Conference of Women Engineers and Scientists, Communication Proceedings, University of Warwick, UK, 14-20 July 1991, p.72 E.