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Student gender differences in the final examination of an introductory engineering course

Konstantinos G. Kalkanis†, Leda G. Boussiakou‡, Efrossini C. Kalkani† & Iris K. Boussiakou*

National Technical University of Athens, Athens, Greece†
King Saud University, Riyadh, Saudi Arabia‡
Leicester University, Leicester, England, United Kingdom*

ABSTRACT: The purpose of this research is to identify the differences between male and female students in an introductory engineering class. In this study, the authors examined the final examination papers of an introductory engineering course of approximately 200 students, half of whom were female. The examination papers were examined regarding the grade, layout and quality, with data on these properties collected, tabulated, plotted and evaluated. Higher grades and lower grades belonged to female students, while best grades had the second highest grading of the best appearance for papers from female students and third best grading of the appearance of the papers from the male students. It was found that male students submitted more averagely organised papers, while female students obtained higher grades than their male counterparts with regard to papers with the best appearance. Furthermore, while female students performed better in generating graphics and descriptions, male students performed better in forecasting and decision making. However, half of the male students exhibited poor handwriting and readability. Remedial measures should be taken early in the semester to eliminate differences.

INTRODUCTION

Student gender differences were analysed in the final examination of an engineering introductory course with the goal to identify key areas and the extent of the differences. Another consideration was to suggest remedial measures early in the semester for all students.

Most universities with engineering curricula have fewer enrolments of engineering female students and generating statistics for general findings that can help the university faculties design measures is imperative.

STUDY OF EXAMINATION PAPERS

At the School of Civil Engineering at the National Technical University of Athens (NTUA), in Athens, Greece, the proportion of female students has reached almost 50%; as such, it was possible to perform this study. Elsewhere, the low level of the enrolment of female students is due to numerous factors that have to be addressed [1]. However, singling out female engineering students for help is not fair to male students [2].

The examination papers were categorised into six groups according to their appearance: from excellent to poor. The research was performed sequentially, starting from the grades received for all students and separately for male and female students. This continued into an evaluation of the layout, arrangement and organisation, and ended with an assessment of the quality and readability of the papers.

In this research, the goal was to help both male and female students in eliminating their weaknesses and developing their strengths. So this study was performed in order to identify the specific weaknesses of male and female students displayed in their final examination papers.

RESEARCH PROCEDURE AND DATA COLLECTION

The research presented in this article refers to gender differences of engineering students, specifically to their performance in a written examination of an introductory engineering course. The course is given during the second semester of their studies in the School of Civil Engineering at the NTUA.

The examination was an open-book and open-notes final examination of an engineering course in *Renewable Energy* and taught in the spring 2006 semester. The course is an introductory course elective for all students that describes the sources of renewable energy, the layouts of plants, and the economics and benefits of plant operations.

The students on the roster enrolled in the course numbered 275. The final examination was given to all the students at the same time and was assessed by the same grader. The students were separated into groups of 40 persons, following the sequence of the alphabetic order of the roster, and were placed in seven different classrooms to take their examination. The differences of the classrooms may have had an effect to all or some of the students; however, this effect was not taken into account in this study.

The main interest of this research was to identify differences in the performance of students due to gender with respect not only to the grades of the examination papers, but also the layout of the text and figures, as well as the readability of the papers.

Some of the examination papers were in perfect condition, with perfect handwriting and an excellent organisation of the text, tables and figures. Some other papers were of a very poor quality, difficult to read, bad handwriting, with the tables badly aligned, figures with crooked lines and with no legends or scales.

A more detailed study was considered in the researchers' efforts to determine the characteristics that discriminate on some of the competences of male and female engineering students. To this end, it was decided to categorise the examination papers in six groups.

The examination papers were divided into six groups according to the following criteria in each group:

- Group 1: Excellent layout of the paper, appealing writing, perfect use of space;
- Group 2: Good appearance of the paper, good use of the available space;
- Group 3: Average appearance of the paper;
- Group 4: Poor appearance, loose writing, scratches, many empty spaces;
- Group 5: Very poor appearance;
- Group 6: Very, very poor appearance.

The research was organised sequentially, starting from the correctness and grades of the papers, entering into the layout, arrangement and organisation, and ending with the quality and readability of the papers. More specifically, the following aspects were examined:

- Grade regarding the correctness of the paper:
  - Overall grading;
  - Overall grading of male and female students' papers;
  - Variation of the best answers.
- Layout regarding the arrangement and organisation of the paper:
  - Classification;
  - Average grades;
  - Trend lines of grading.
- Quality regarding the readability of the paper.

The collected data presented in this research were presented in tables and plotted in column charts or line diagrams. The results shown in the tables and figures are evaluated and conclusions drawn regarding the gender differences of the examination papers. These gender differences, if known at the beginning of the semester, can be addressed in order to eliminate the weaknesses of male and female students.

Grades

The participation of the students in the examination was a little more than 75% and only a total of 210 students took the examination. Within the total number of enrolled students, almost 50% were men and 50% were women. The participation of the students to the examination, and hence to this study, is shown in Table 1. From the 210 students who undertook the examination, 198 were given a grade above 12 out of 50 points (maximum) and were included in the study.

The final examination included five questions, each one of which was allocated 10 points. Those students with correct answers could reach the maximum of 50 points. The time interval available to the students was 1½ hours, within which they had to answer the five questions given in the examination. The five questions in the examination that covered the subjects taught, along with the context and skills tested, are listed in Table 2.

Table 1: The participation numbers of students in the study.

Item	Male	Female	Total
Registered students	138	137	275
Absent students	29	36	65
Examined students	109	101	210
Graded from 0 to 12 points	7	5	12
Graded from 12 to 25 points	37	29	66
Graded from 25 to 50 points	65	67	132
Students included in this study	102	96	198

Table 2: Description of the five questions on the final examination.

Question #	Subject	Context	Skills
Question 1	Energy production	Data processing	Calculations, bar charts
Question 2	Energy consumption	Data processing, evaluation	Calculations, bar charts, forecasting
Question 3	Solar energy (thermal)	Layout, main structures	Description, sketches of plant layout
Question 4	Wind energy	Data processing, design	Calculations, scatter diagram
Question 5	Electric energy	Engineering economics	Calculations, decision making

Regarding the separate answers to the five questions, the number of students with the excellent mark of 10 points in each of the five questions was considered. For each question in the examination, the number of successful students over the total number of students with grades above 25 points gave the percentages listed in Table 3. The results were calculated as the frequency of the occurrence of the highest grade answers over the total answers for the same question.

Table 3: Frequency of the highest grades in the five questions.

Question #	Male Scores	Female Scores	% Male	% Female
Question 1	8	11	6.06%	8.33%
Question 2	53	50	40.15%	37.88%
Question 3	14	16	10.61%	12.12%
Question 4	11	24	8.33%	18.18%
Question 5	7	5	5.30%	3.79%

Layout

Each of the six groups of examination papers contained a total of 33 papers, with total differing between the male and female students. The papers from the male and female students in each group, along with the total number of papers and percentages of male students in each group, are shown in Table 4.

Table 4: The classification of student papers in their groups.

Group	Male	Female	Total	Male %
Group 1	4	29	33	12.12%
Group 2	16	17	33	48.48%
Group 3	18	15	33	54.54%
Group 4	27	6	33	81.81%
Group 5	21	12	33	63.63%
Group 6	16	17	33	48.48%
Total	102	96	198	51.51%

The grade average was calculated for each of the six groups. The averages of the grades were also computed separately for male and female students. The results are shown numerically in Table 5. The average values of grades for the papers within each group range from 35.61% to 17.97% in Groups 1 to 6. The maximum average value is a little less than 36% and is present in Group 2.

Table 5: Average values of the grades within the groups.

Group No.	Male	Female	Total
Group 1	32.50	36.03	35.61
Group 2	33.75	37.53	35.70
Group 3	34.72	31.47	33.24
Group 4	32.62	28.80	31.93
Group 5	23.14	22.67	22.97
Group 6	18.00	17.94	17.97

The average grades of male and female papers become lower from Group 1 to Group 6. The average grades of papers from the males were found to be lower than those from female students in Groups 1 and 2, while they were higher in Groups 3 and 4. In Groups 5 and 6, the average values for papers from the male and female students remained at almost the same levels, although they were less than 25 points (out of a maximum of 50 points). The average increased from Group 1 to Group 2 for female papers and to Group 3 for male papers.

Quality

The values of grades for male and female students in each group, when placed in a sequence from high to low values, have a trend line that is characterised by a slope and an intercept. The slope indicates how fast the value of the grade drops, while the intercept shows the maximum virtual value of grade in the group. The slopes and intercepts of the six groups for the female and male students are listed in Table 6. The slope results show a decrease of the slope for both the male and female results, indicating small differences in the sequence of grades and hence a smaller drop of grades when moving from Group 1 to Group 6. The intercept results show a larger score for male papers in Group 3 and for female papers in Group 2.

Table 6: The classification of the students' papers in terms of slope and intercept.

Group	Male Slope	Female Slope	Male Intercept	Female Intercept
Group 1	-5.00	-0.76	45.00	47.40
Group 2	-1.34	-1.47	45.18	50.77
Group 3	-1.15	-1.04	45.61	39.78
Group 4	-0.76	-1.74	43.23	34.93
Group 5	-0.25	-0.38	25.93	25.17
Group 6	-0.35	-0.33	20.95	20.92

In the first four groups, the quality of writing was estimated within a scale of zero (poor handwriting and difficult to read) to five (excellent handwriting and very easy to read). The results, shown numerically in Table 7, indicate that almost 50% of the male students were in the category of poor handwriting and poor readability of their papers. However, this level of poor readability belonged to almost 25% of the female papers. The range of female papers was expanded between a scale of 0 and 5, and had more than 7% frequency of occurrence at scale 5, which corresponds to excellent appearance and readability of the papers.

Table 7: Quality scale on the readability of the papers in the first four groups.

Quality Scale 0-5	Quality Description	Male Frequency	Female Frequency
0	Very Poor	20.00%	5.97%
1	Poor	49.23%	23.88%
2	Average	24.62%	31.34%
3	Good	6.15%	19.40%
4	Very good	0.00%	11.94%
5	Excellent	0.00%	7.46%

DATA PROCESSING

Grade

The data from Table 2 show that 198 papers were processed in this research. The grades allocated to the 198 students were sorted in decreasing order of magnitude, as shown in Figure 1. The sequence of grades – from maximum to minimum – is on a smooth line without distinct blocks of highs and lows or stepwise structures with large steps.

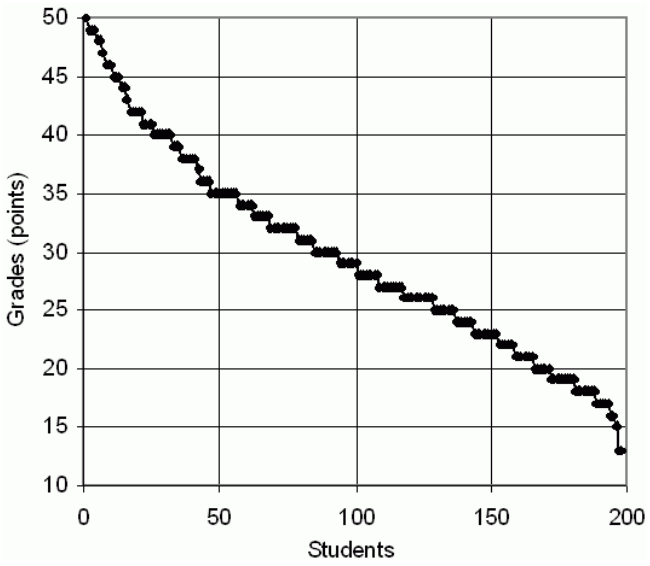

Figure 1: Examination of the grades for the 198 students sorted in descending order.

Since almost 50% of the students in the course were male and 50% female, the examination grades were also plotted in sequence of higher to lower values separately for male and female students in two separate lines, as shown in Figure 2. This result indicates that higher grades – above 32 points (64%) – and lower grades – below 23 points (46%) – belonged to female students. Medium grades – between 23 and 32 points (46% to 64%) – belonged equally to male and female students.

The column chart of Figure 3 demonstrates the results in Table 3. The chart shows the gender differences of success (highest grades) for the five questions. Figure 3 also shows that some questions had more successful answers than others, such as Question 2, which required only simple calculations, a bar diagram and forecasting. Comparing the results of Table 3 to the skills tested in each question in Table 2, one can determine that for those skills required to carry out calculations and bar charts in Question 1, female students performed better than their male counterparts. Also, in performing the sketches and scatter diagrams required in Questions 3 and 4, as well as the descriptions for Question 3, female students performed better.

Contrastingly, in the cases of the forecasting needed in Question 2 and decision making in Question 5, male students performed better than the female students. Both genders performed very well in undertaking calculations.

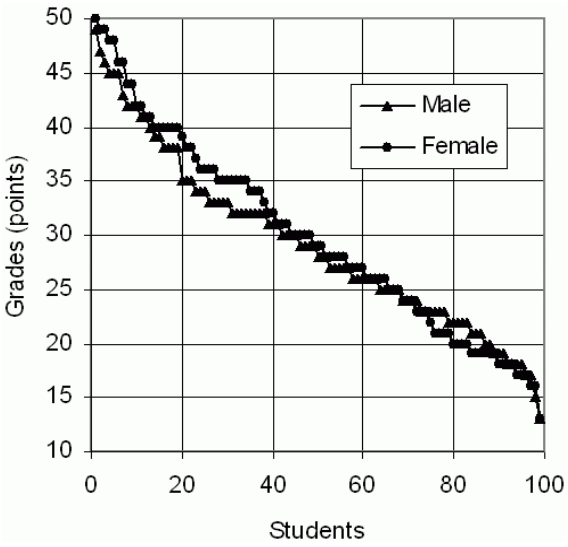

Figure 2: Total examination grades for the male and female students separately.

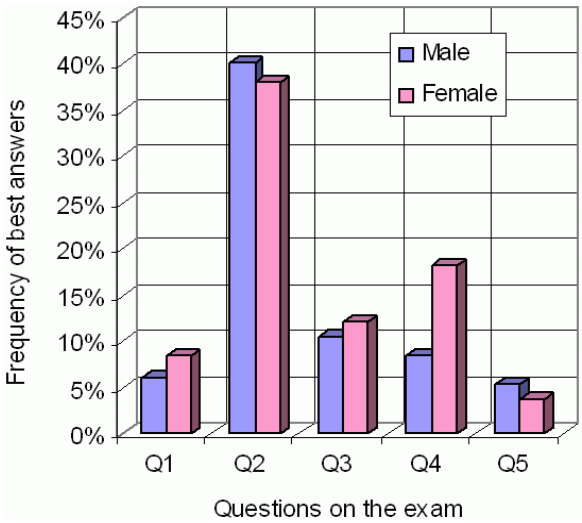

Figure 3: The male and female success rates in each of the five questions of the examination.

Layout

A graphical representation of the information in Table 4 is given in the 3-dimensional-column chart of Figure 4. It can be easily seen from this chart that the level of participation of the male student groups increased for the middle groups, while the participation of female students increased for the first and last groups, with lower values in the middle groups. This classification of male and female students into groups indicates that male students have more average quality papers; while the best-organised papers, as well as the worst-organised papers, were generated by female students.

To connect the finding on the appearance of the papers to the grades of the papers, the grades in each group were plotted separately for the male and female students. The grading was made considering the correct answers to the questions and the completeness of the charts and diagrams, and not the appearance and the quality of the presentation of the paper.

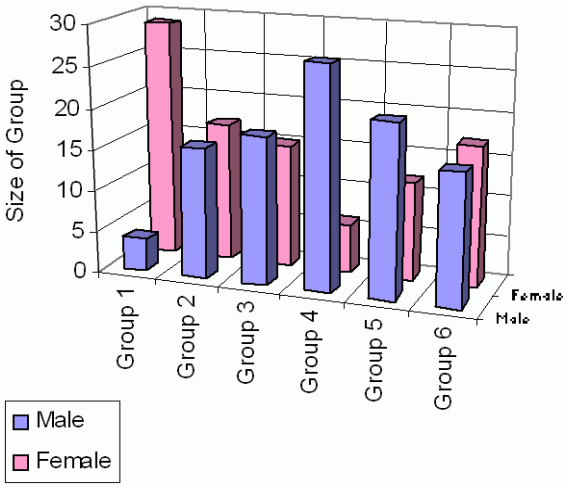

Figure 4: Classification of the examination papers in groups and identification of the number of male and female papers in each group.

The column chart of Figure 5 presents the data from Table 5 and shows the grade average of the six groups separately for male and female papers, as well as the total average. The information in Figure 5 shows that increased grades correspond to Group 2 and not to Group 1, and in those two groups, female papers obtained higher grades than male papers. In Groups 3 and 4, male papers were graded more highly than female papers. In Groups 5 and 6, the grades were low, below passing grade, with only a small differentiation between male and female papers. One of the findings from the column chart is that the best grades were not allocated to the papers with the best appearance in Group 1, but the second best appearance papers from Group 2.

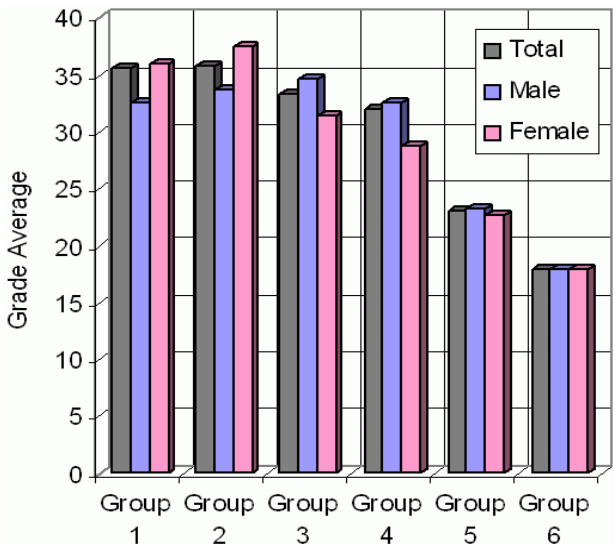

Figure 5: Average grades within each of the six groups examined.

The plotted grades versus number of students are shown in Figure 6 for the four first groups, listed from top to bottom separately for male and female students. The results of the first and second groups show that the grades of the female papers were higher than the grades of the male papers. In the third and fourth groups, there reversal of lines indicates that the grades of the female papers were lower than the grades of the male papers. In the fifth and sixth groups (not plotted in Figure 6), the grades were very low for both the male and female papers and were almost the same.

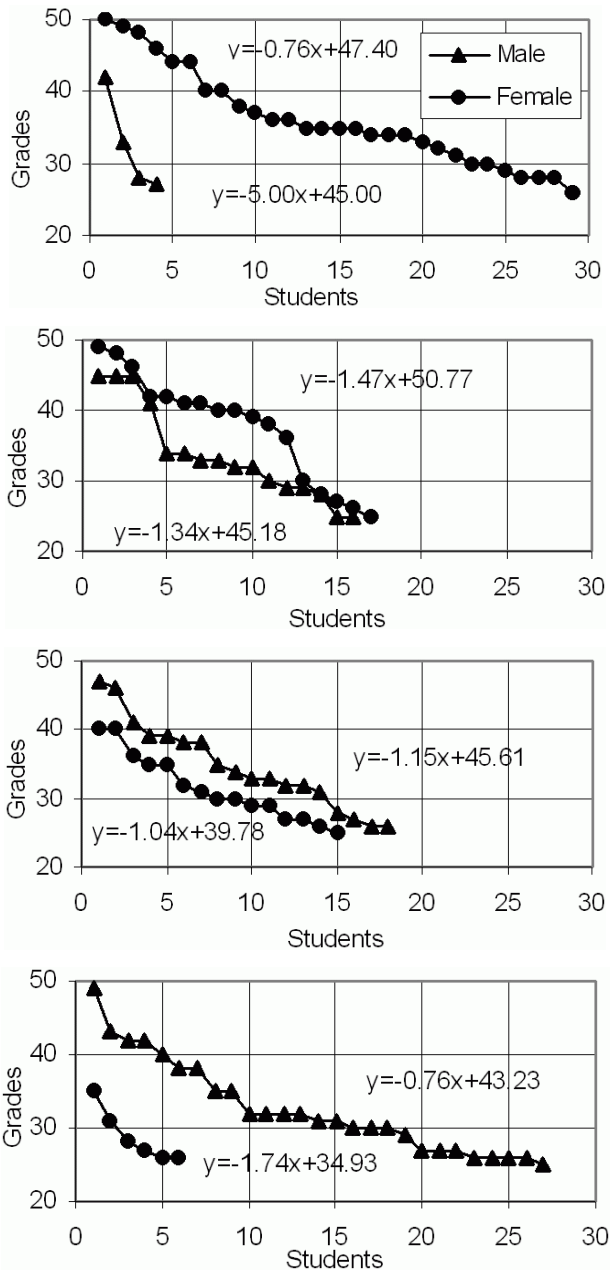

Figure 6: Examination grades versus students for the male and female papers for Groups 1 to 4 from top to bottom.

The trend lines or linear fit lines of the data, although not shown on the diagrams, give the first order equations shown in each diagram. The equations are shown separately for the male and female data series and are placed close to their respective lines. The slope and intercept of these equations are detailed in Table 6.

Quality

The graphical representation of the results of Table 7 are shown as a line diagram in Figure 7, where a displacement of the maximum frequency of the occurrence of the quality scale 1 for male students is moved to scale 2 for female students, who have higher participation towards higher indices than male students.

RESULTS

The grader of the examination papers considered only the correct answers to the questions and the completeness of charts and diagrams, and not the appearance and organisation, the quality of presentation and readability of the papers. In each examination question, there were four or five sub-questions that were graded separately, and the sum gave the grade for the question. The research presented here considers all the examination papers from different points of view.

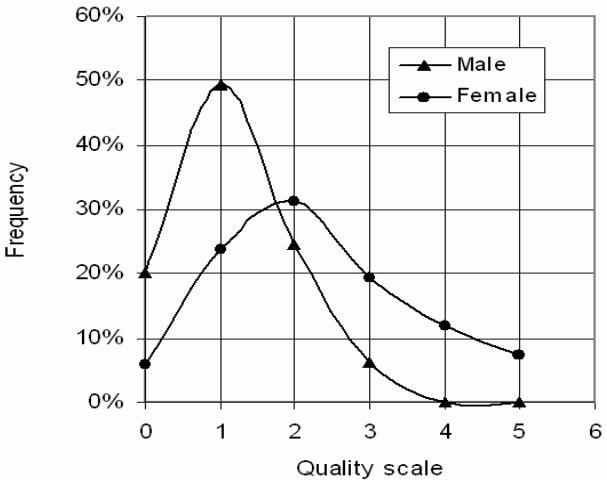

Figure 7: Frequency of occurrence for the quality scale.

The results can be classified as follows:

Grades

- Higher grades (above 64%) and lower grades (below 46%) belonged to female students. Medium grades (between 46% and 64%) were allocated equally to male and female students;
- The best grades were not given to the best appearance papers, but to the papers that had the second grade of appearance for females and the third grade of appearance for males.

Layout

- The male students submitted more of the averagely organised papers, while the best organised papers and the worst organised papers came from the female students;
- With regard to the best appearance of papers, the female students obtained higher grades than the male students, although the worst appearance papers yielded higher grades for the male students than for the female students;
- Female students performed better and scored higher grades in undertaking graphics and descriptions, while male students performed better in forecasting and decision making, with both genders doing well in carrying out calculations.

Quality

- Half of the male students were in the category of poor handwriting and poor readability of their examination papers, while only one quarter of female students fell into the same category; additionally, more than 7% of female students belonged to the excellent handwriting and readability category.

Similar results were noted in the same course from previous years, although no detailed study was performed at the time. The main characteristics easily identified in the group of engineering students of the present study is as follows:

- The papers with the best appearance did not obtain the best grades, possibly because those students who kept a high quality of handwriting and appearance did not have adequate time to finish all the subjects and questions;
- The best grades were given to examination papers that did not have all the details, but the sequence of calculations and charts was fast, the space used was small and the examination time was utilised wisely.

DISCUSSION

Although the level of enrolment of female students in engineering programmes differs around the world, the NTUA has achieved a rate of 50% female students enrolled in its School of Civil Engineering. Elsewhere, the low level of enrolment can be unsatisfactory, even if a virtual guarantee of employment is present; this is due to numerous factors, including the belief that technical education is primarily a male domain [1].

In other research, the spotlighting on female students is discussed, which refers not to overt or tacit sexism, but rather to identifying gender differences with the intention to help [2]. In such cases, engineering programmes for women should be directed to all students, and be based on academic and not demographic criteria. Institutions should expand the opportunities for women in engineering programmes and conduct engineering programmes that emphasise the pre-emption of non-professional behaviour and exclude other biases [2].

Some researchers have found that female students are discouraged in studying engineering because of isolation in the first two academic years of general education, the inability to see the relevance of highly theoretical basic courses, negative experience in laboratory courses, the classroom climate, lack of role models and a relative lowering of self esteem.

Research has led to the organisation of faculty workshops to develop productive policies in recruiting and retaining women in engineering [3]. A key message of these workshops is to make faculty members more sensitive to issues that women face in the classrooms so that it enhances the learning environment for all students. The latest research refers to the culture of engineering education and the level of interaction with regard to gender performance [4].

There are four elements of learning procedures and styles according to Kolb as follows:

- Abstract conceptualisation considers the theory and refers to thinking;
- Reflective observation refers to watching and observing;
- Concrete experience refers to sensing and feeling;
- Active experimentation refers to doing [5].

Although Kolb identified four types of learners, newer research considers more categories, along with a scale of intensity for each type [5][6]. The students engaged in the above research were examined in the above elements of learning and the results were evaluated within the three aspects of grade, layout and quality. The main elements in addressing the learning styles of the students covered the elements of thinking, watching, sensing/feeling and doing, which were tested by using written examinations that gave quantitative answers. The quality of these elements in the examination papers was also analysed. Faculty can apply the Learning Cycle independent of the discipline taught so as to improve and enhance engineering education [7].

There are six levels of educational objectives according to Bloom's Taxonomy, namely three lower levels and three higher levels [8]. Usually, undergraduate education deals almost exclusively with levels one to three, which refer to knowledge, comprehension and application, while graduate education mainly deals with levels four to six, which address analysis, synthesis and evaluation [9]. In this study, the researchers looked at the undergraduate educational objectives, which cover knowledge, comprehension and application, and those objectives were graded and compared between male and female students. This research refers to a written examination and not an oral one. From a survey of former students, the researchers found that students should be encouraged to practice, as well as develop their oral and written technical communication skills, while attending the university [10].

Students' abilities, plus their strengths and weaknesses in an engineering course, were researched in such a way so that the students themselves generated their own SWOT analysis [11]. In this research, a test should be prepared to have the students assess their strengths and weaknesses as these are revealed in their examination papers. The present research looked at the strengths and weaknesses of the students, while also analysing their attitudes on their notions and understanding of their strengths and weaknesses regarding learning and the course outcomes.

The researchers did not consider the emotional intelligence (EQ) level of the students; EQ involves the awareness and ability to manage one's emotions in a healthy and productive manner. Other definitions consider *the ability of a person to understand his feelings and the feelings of others, to distinguish and use his feelings as guideline in his thinking and his actions* [12]. Techniques of emotional intelligence can be applied in the classroom in order to create a positive climate where negative emotions can be turned into positive ones [13].

Emotional intelligence consists of four directions: two personal (self-knowledge and self-management) and two social (social knowledge and social management). Each category of the four directions involves emotional skills, along with the mental skills utilised by the person to perform successfully in the workplace [14].

In this study, the gender differences were not correlated to the emotional intelligence levels of the students. Instructors have to consider differences in the emotional intelligence levels of their students, which can range from pessimism to optimism [13]. Other researchers found that students differ not only in the levels of their motivation and attitudes towards the style of teaching and learning, but also to different responses regarding classroom environments and instructional practices [15].

The main negative emotion expressed by students is anxiety, without further researching if this is short-term or long-term in nature and what the reasons are behind this [13]. Other researchers have studied students' anxiety in examinations related to a short-term or a long-term emotion, as well as their self-image, and not related to study skills, problem solving skills or avoidance in engaging in difficult problem solving [16].

Researchers have found that the main positive emotion expressed by students in a certain engineering class is pride, which is mainly related to successful alumni and the prestige of the school, while the second positive emotion is trust regarding the friendliness and accessibility of teachers [13]. Elsewhere, researchers found that the accessibility of the instructor is more important than the perceived course workload and the expected grade in the course [17].

In this research, if the results of the performance of students are based on anxiety and disappointment or pride and trust, the instructors have to work on those attitudes during the semester for both male and female students. Researchers in similar situations found that the challenges for both professors and institutions are to educate teachers in applying new approaches and techniques of teaching and learning in engineering education [18]. Hence, early tests on the course, as well as an evaluation of the grade, layout and quality aspects of the papers, along with determining the emotional intelligence levels of individuals and the class as a whole, will lead to correction measures in the course that will result in the success of the students concerned.

CONCLUSIONS

In this research the examination papers of an introductory engineering course were analysed regarding the grade, layout and quality, with the goal to determining the differences between female and male students. The grades are based on the correct answers and the completeness of charts and diagrams, and not on the layout and quality of the papers. Higher grades and lower grades belonged to female students. Medium grades belonged equally to male and female students. However, the best grades are given to those papers with the second best appearance for female students and the third best appearance for males.

It was also found that the male students had more averagely organised papers, while female students had the best and worst organised papers. The female students obtained higher grades than the males in papers with the best appearance papers, while male students scored higher grades in papers with the worst appearance.

Furthermore, the female students performed better in undertaking graphics and descriptions, while male students performed better in forecasting and decision making.

Half of the male students displayed poor handwriting and readability, while only one quarter of female students belonged to the same category. It was found that 7% of female students belonged to the excellent handwriting and readability scale.

In short, the papers with the best appearance did not obtain the best grades, and students who gained the best grades did not have high detail in their papers, but showed a faster sequence of answers to the questions.

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