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A STATISTICAL ANALYSIS OF THE SOUTH AFRICAN NATIONAL BOARD EXAMINATIONS FOR INTERN MEDICAL TECHNOLOGISTS FOR THE PERIODS 2008-2012

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ABSTRACT

Background: The main role of the Society of Medical Laboratory Technologists of South Africa (SMLTSA) is to promote and regulate the profession of Medical Laboratory Technology in South Africa (S.A.). The National board examinations for Intern Medical Technologists (MTIN) are co-ordinated by the SMLTSA on behalf of the Health Professional Council of South Africa (HPCSA). Passing these examinations is the qualifying criterion for a career in Medical Laboratory Technology. This qualification in Biomedical Technology is unique to S.A. and as such literature regarding the performances of MTIN in the National board examinations is very limited.

Objective: No previous research has been conducted to investigate the performances of MTIN in the National board examinations. For that reason, the examination scores for the periods 2008 to 2012 were analysed for variances in mean scores of MTIN who did their internship at different training laboratories, and who studied at different Higher Educational Institutions (HEI's) as well as results of MTIN from the province of Gauteng, who specialised in four different disciplines. An analysis of the pass rate for the country was also done.

Method: The One-way analysis of variance (ANOVA) and Pearson Chi-square test were used to detect statistical significant differences in mean performance scores between these groups. Differences were considered significant at a p-value of <0.05

Results: Several statistical significant differences in performance scores between groups were uncovered.

Conclusion: Statistical findings indicated poor overall performances in these examinations for the periods 2008 to 2012. It is therefore suggested that an in depth investigation be implemented into the suitability of higher education training and the adequacy of Internship programmes offered by training laboratories.

KEYWORDS

Society of Medical Laboratory Technologists of South Africa (SMLTSA), Health Professional Council of South Africa (HPCSA), Intern Medical Technologists, The One-way analysis of variance (ANOVA, Pearson Chi-square test).

INTRODUCTION

SMLTSA was established in 1951 after the consolidation of the Natal, Southern Transvaal and Cape Societies. This Society plays an important role in the quality assurance of training and in the examination/s of Medical Technologists.[1] SMLTSA is an affiliated Society under the directive of the HPCSA. The HPCSA determines minimum standards for education and training to ensure that the interests of the public is protected.[2]

Student Medical Technologists (SMT's) that successfully graduate from HEIs are required to find employment at a registered training laboratory. Once SMT's have found employment they are required to register as MTIN with the HPCSA. Thereafter MTIN are required to enrol with SMLTSA in the specific discipline that they are planning to write the National board examination in, as soon as they commence with their internship. Success in this examination is a requirement to register and practice as a qualified Medical Technologist (MT) in S.A.[3] These examinations are co-ordinated by SMLTSA on behalf of the HPCSA.[1]

During the 12 month internship period, the training is based on a discipline specific syllabus guide, provided by SMLTSA.[3] There are eleven registered disciplines: Clinical Pathology (which includes three disciplines, Haematology, Chemical Pathology and Microbiology) or mono-specialised fields such as Blood Transfusion, Anatomical Pathology (Histology and Cytology), Chemical Pathology, Cytology, Cytogenetics, Haematology, Immunology, Microbiology, Virology or Pharmacology. Eighty present of all students prefer to write Clinical Pathology and the remaining 20% choose to write a mono-specialised discipline.[1]

The examination pass rates for the last decade have shown that although students have successfully obtained their higher qualification the majority find it difficult to pass the National board examination in a chosen discipline (Academic advisory committee meeting, University of Johannesburg, personal communication, October 2013). HEI's and training laboratories are greatly concerned with the poor performances in these exami-

nations (Academic advisory committee meeting, University of Johannesburg, personal communication, October 2013).

To date, no statistical data has been published to explore these poor performances. For the periods 2008 to 2012, the total number of MTIN who wrote the Clinical Pathology examination in S.A. was 844. Of the 844 who wrote only 258 (31%) students passed the March examinations and in the September examinations, only 98 (12%) students passed as captured on the SMLTSA database, 2014. These figures have raised concerns as to what the reasons might be for these low pass rates and these reasons definitely warrant further investigation. This unique pilot study of the performances of MTIN related to the National board examinations was consequently conducted in one of South Africa's largest provinces.

METHODOLOGY

Ethical considerations

Prior approval and permission was received to conduct this study from the Academic Ethics Committee of the Faculty of Health Sciences at the University of Johannesburg (No. AEC01-08-2014) and the SMLTSA. Access to the data was limited to the researcher, statistician, supervisor and co-supervisor of this research project. The data was coded and stored electronically in password-protected files.

Analysis strategy

This study used a retrospective, multi-year design to analyse student performances related to the National board examination for Medical Technologists for the periods 2008 to 2012. These examinations included two 3-hour papers each held on the same day. MTIN are expected to achieve a minimum of 50% for each paper. In the case of Clinical Pathology, MTIN are required to obtain 50% in each discipline across both papers and an overall pass mark of 50%.[4]

There are three HEIs that offer Biomedical Technology and four training laboratories that offer Internship programmes in the province of Gauteng S.A. The aim of data selection was to analyse examination results in this province for the four main disciplines.

The quantitative sample size included 854 National board examination results from three private sector training laboratories and one government sector training laboratory. Six hundred and twenty eight examination results from three HEI's, 628 discipline specific examination results that included Clinical Pathology, Haematology, Chemical Pathology and Microbiology and lastly an overall of 1212 National board examination results representing the frequency distribution percentages of MTIN pass and fail totals for the periods 2008 to 2012, as indicated in Figure 1.

Statistical analyses

The quantitative data obtained from the National board examination results was transferred to a Microsoft Excel spreadsheet and analysed using the SPSS programme (IBM SPSS Statistics for Windows, Version 21.0, 2012). There was one dependent variable (examination scores), which was compared for a number of different subgroups (four laboratories, three HEI's, and four different disciplines) to compare the variability in examination

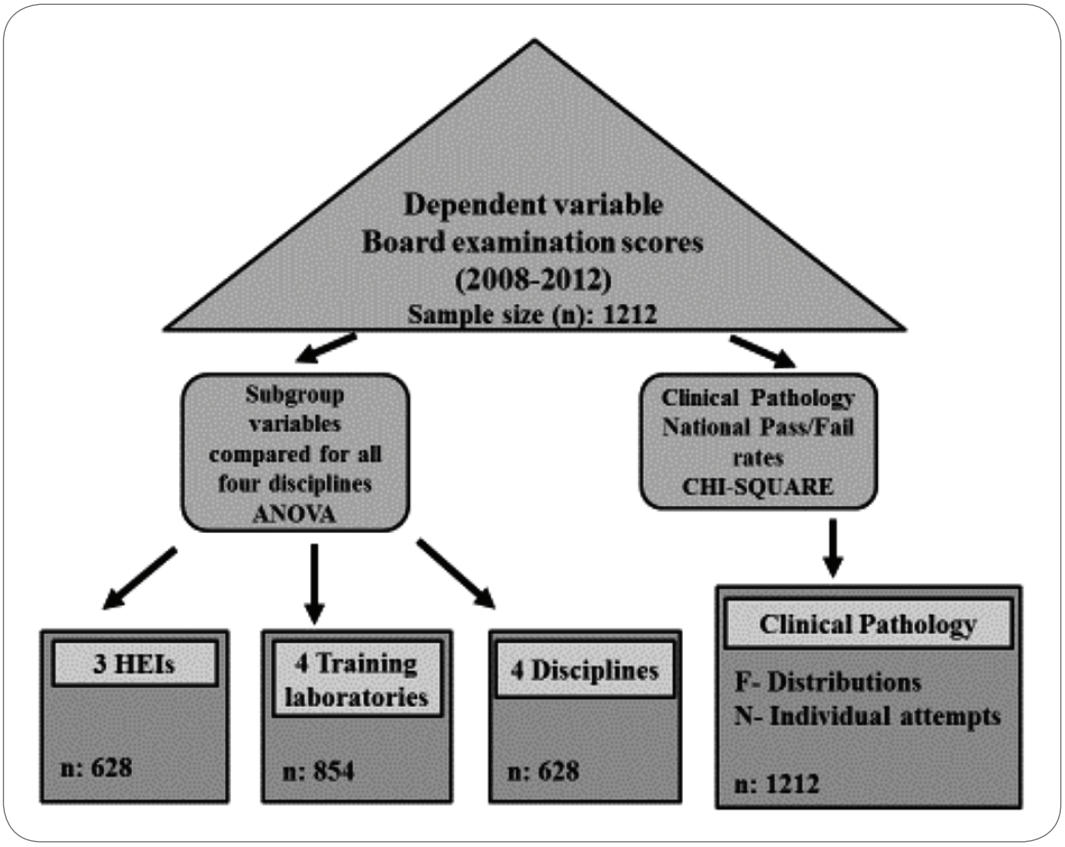

Figure 1. Analysis strategy

scores. Based on the normality of distribution findings using the Shapiro-Wilk test and the Kolmogorov-Smirnovtest the parametric One-way between groups (ANOVA) was used for comparative studies. The Hypothesis tested was H_0 indicated that the mean performance of MTIN was equal for each of the comparisons. H_1 indicated that mean performance of MTIN was not equal.

Post-hoc testing was performed using the Scheffe (relies on homogeneity of variance) or Tamhane test to indicate the statistical significant differences between the different groups. Differences were considered significant at a p-value of <0.05.[4,5]

The second set of results, which included 1212 National board examination results for Clinical Pathology were analysed using the Pearson Chi-square test to compare the proportion of pass and fail rates for the periods 2008 to 2012. Differences were considered significant at a p-value of <0.05.[4]

RESULTS

Criteria governing the admissibility of the data

Multiple variables were tested for this study for normality across a range of groups using the quantile-quantile plot (Q-Q plot), numerical method, and the Shapiro-Wilk test, and the Kolmogorov-Smirnov test.[4]

The Shapiro-Wilk test is a very powerful test, and can detect deviations in normality in smaller sample sizes, and because of these properties this test was used in this study. The Kolmogorov-Smirnov test (KS) is based on the largest vertical difference of the hypothesised and empirical sample distribution. The KS test statistic is meant for testing H_0 - the data follows a specified distribution and H_1 - the data does not follow the specified distribution.[6]

These tests show that the distribution of examination results (the mean, median and mode) for laboratories, HEI's and disciplines were fairly close and that there was no excessive skewness, suggesting a normal distribution. Both the Shapiro-Wilk test and the Kolmogorov-Smirnov test indicated that the p-value was greater than the chosen α-level (alpha 0.05), which means that the hypothesised value was not rejected indicating a normal distribution of data.

A comparison of the mean performances of interns registered training at four different laboratories for the periods 2008-2012

A total of 854 examination results from the four selected training laboratories (Laboratory 1, 2, 3 and 4) were statistically analysed using the one-way ANOVA method. The Hypothesis tested: H_0 = The mean performance of MTIN at three private sectors and one government sector training laboratory was equal. H_1 = The mean performance of MTIN at three private sectors and one government sector training laboratory was not equal.

The differences in these mean performances of MTINs are indicated in Table 1. The disciplines included are Clinical Pathology, Haematology, Chemical Pathology and Microbiology. The (N-values) are not displayed to ensure confidentiality and to avoid the possibility of laboratories being identified.

Test for homogeneity of variances

The Levene's homogeneity test of variances was used to test if score variances were the same for each of the four laboratories. This was indicated by a significance value of 0.837. The Sig. value is >0.05 which indicates that there is no violation of homogeneity of variance present.[4]

ANOVA for laboratory groups

Between-group and within-group analysis was performed,

Table 1. Comparison of results for different training laboratories

LABORATORY	N	MEAN %	STD. DEVIATION	MULTI COMPARISONS	MEAN DIFFERENCES	SIG
Lab 1	-	47.7	11.339	Lab 2	2.062	.475
				Lab 3	-3.775	.678
				Lab 4	-2.539	.157
Lab 2	-	45.7	11.868	Lab 1	-2.062	.475
				Lab 3	-5.837	.292
				Lab 4	-4.601*	**.000***
Lab 3	-	51.5	10.363	Lab 1	3.775	.678
				Lab 2	5.837	.292
				Lab 4	1.236	.981
Lab 4	-	50.3	11.592	Lab 1	2.539	.157
				Lab 2	4.601*	**.000***
				Lab 3	-1.236	.981
		48.9	11.732			

** The mean difference is significant at the < p 0.05 level*
a. Scheffe test used for multiple comparisons
b. N- values not displayed due to confidentiality

Table 2. Comparison of results for different Universities

LABORATORY	N	MEAN %	STD. DEVIATION	MULTI COMPARISONS	MEAN DIFFERENCES	SIG
UN 1	134	52.7	12.278	UN 2	3.828*	.015*
				UN 3	3.949*	.004*
UN 2	207	48.9	12.212	UN 1	-3.828*	.015*
				UN 3	.121	**.999**
UN 3	287	48.8	10.386	UN 1	-3.949*	.004*
				UN 2	-.121	.999
	628	49.7	11.521			

** The mean difference is significant at the < p 0.05 level*
a. Tamhane test used for multiple comparisons

which included the sums of squares, degrees of freedom, mean squares, a significant F test and significance value. A large F ratio (7.927) indicated that there is more variability between groups than there is within each group. A significant F test (<0.05) indicates that the null hypothesis which states that group means are equal can be rejected.[4]

Further statistical analysis using post-hoc testing was performed to compare the results of the different laboratories. Table 1 indicates a statistical significant difference at the $p < 0.05$ level in the performances of MTIN between laboratory 2 and 4 ($F(3, 850) = 7.9$, $p = 0.00$). Laboratory 4 achieving a higher score compared to laboratory 2. The effect size, calculated using eta square (divide sum of squares for between groups by the total sum of squares), was 0.03 (small) as per Cohen's (1988) criteria: small effect size = 0.01, medium effect size = 0.06 and large effect size = 0.14. Therefore, the H_0 which states that the mean performances of MTIN at three private sectors and one government sector training laboratory were equal was rejected.[7]

A comparison of the mean performances of students in the National board examinations from three different HEI's for the periods 2008-2012

A total of 628 results from the National board examination on students who obtained their qualification at the three selected HEI's (University 1, 2 and 3) were statistically analysed using the one-way ANOVA method. The Hypothesis tested: H_0 = The mean performance of MTIN that studied at three HEI's was equal. H_1 = The mean performance of MTIN that studied at three HEI's was not equal. The observed differences in mean performances of MTIN are indicated in Table 2. The (N-values) could be displayed because they are close to each compared to the mean values for the laboratories, which avoid the possibility of Universities being identified.

Test for homogeneity of variances

The Levene's homogeneity test of variances was indicated by a significance value of 0.014 (Sig.). The Sig. value was not >0.05

Table 3. Comparison of results for different disciplines

LABORATORY	N	MEAN %	STD. DEVIATION	MULTI COMPARISONS	MEAN DIFFERENCES	SIG
Haematology	47	51.9	14.693	Microbiology	-.882	.983
				Chemical Pathology	1.032	.978
				Clinical Pathology	3.124	.366
Microbiology	66	52.8	10.316	Haematology	.882	.983
				Chemical Pathology	1.914	.847
				Clinical Pathology	4.006	**.071**
Chemical Pathology	52	50.9	13.502	Haematology	-1.032	.978
				Microbiology	-1.914	.847
				Clinical Pathology	2.092	.669
Clinical Pathology	463	48.8	10.987	Haematology	-3.124	.366
				Microbiology	-4.006	**.071**
				Chemical Pathology	-2.092	.669
	628	49.7	11.21			

** The mean difference is significant at the < p 0.05 level*
a. Scheffe test used for multiple comparisons

Table 4. National Pass and fail percentages related to the Clinical Pathology National board examinations for the periods 2008 to 2012

	2008	2009	2010	2011	2012	TOTAL
% Pass	60.2% (n-171)	37.3% (n-94)	37.5% (n-99)	32.0% (n-65)	34.0% (n-71)	500
% Fail	39.8% (n-113)	62.7% (n-158)	62.5% (n-165)	68.0% (n-138)	66.0% (n-138)	712
Total	284	252	264	203	209	1212

a. Chi-square test for independence

which indicates violation of homogeneity of variance present.[4]

ANOVA for Universities

Between-group and within-group analysis was performed which included the sums of squares, degrees of freedom, mean squares, a significant F test and significance value. The significance value (0.002) comparing the groups (Universities) is <0.05, so we could reject the null hypothesis.[4] However, since the variances are significantly different a more robust test for equality of means was performed using the Brown-Forsythe test. Instead of dividing the mean square of the error, the mean square is adjusted using the observed variances of each group. The significance value of the Brown-Forsythe test (0.003) is <0.05. Both the between group and Brown-Forsythe test were <0.05, thus the null hypothesis can be rejected. Therefore further Post hoc testing followed using the Tamhane test.[4]

In Table 2 the Tamhane Post-hoc testing indicated a statistical significant difference at the $p < 0.05$ level in the performance scores between Universities 1, 2 and 3 ($F (2, 625) = 6.1$, $p = 0.03$). Students who qualified at University 1 achieved a higher score compared to universities 2 and 3. The effect size, calculated was 0.02 (small) as per Cohen's (1988) criteria: small effect size = 0.01, medium = 0.06 and large = 0.14. Therefore, the H_0 which stated that the mean performances of MTIN from three HEI's were equal was rejected.[7]

Mean performances for Clinical pathology, Haematology, Chemical pathology and Microbiology in the National board examination for the periods 2008-2012

The mean performances for each discipline for the periods 2008 to 2012 are indicated in Table 3. The Hypothesis tested: H_0 = The mean performance of MTIN in the four main disciplines was equal. H_1 = The mean performance of MTIN in the four main disciplines was not equal. The overall mean scores for the selected four disciplines were effectively close to one another. However the overall percentage for the mean performance scores obtained in each discipline were very low indicating that most MTIN just managed to pass these examinations with a minimum required score of 50%.

Test for homogeneity of variances

The Levene's homogeneity test of variances was indicated by a significant value of 0.076. The Sig. value is >0.05, which indicates that there was no violation of homogeneity of variance present.[4]

ANOVA of discipline categories

Between-group and within-group analysis was performed, which included the sums of squares, degrees of freedom, mean squares significant F test and significance value. An F ratio (0.019) indicated that there was more variability between groups than there was within each group. A significant F test (<0.05) indicates that the null hypothesis which states that group means are equal can be rejected.[4]

The Scheffe Post-hoc testing in Table 3 indicated that there was no statistical significant difference at the $p < 0.05$ level in the performances of students between the four disciplines ($F (3, 624) = 3.340$, $p = 0.019$). Therefore, the H_0 which stated that the mean performance of MTIN in the four main disciplines was equal was accepted.

The Clinical Pathology National Board examination pass and fail percentages for MTIN for the periods 2008 to 2012

The Chi-square test for independence was used to explore the relationship between MTIN who passed and failed the National board examinations. This test compared the percentage of proportions of cases that occurred for Clinical Pathology, which included all results for the periods 2008 to 2012 as indicated in Table 4.

Test for violation of assumption of the chi-square

Further investigations were necessary in order to verify if any assumptions of the chi-square concerning the minimum expected frequency counts had been violated. The minimum expected cell frequency should be 5 or greater. There were no violations as all expected cell sizes were greater than 5 (in this study, greater than 24.75). The Pearson Chi-Square value should be <0.05. In this case the value was 0.00 which concludes that the result was significant.[4]

The Phi coefficient

The effect size is indicated by the Phi coefficient value (0.465), which is a correlation coefficient, and can range from 0 to 1. A higher value will indicate a stronger association between two variables. As per Cohen's (1988) criteria there was a statistical significant difference with a large effect size: 0.1 for small effect, 0.3 for medium effect and 0.5 for large effect (Cohen, 1988),[7] between these percentages (x^2 (9,n=1212)=262.183,p=.00,phi=.47). Therefore, the H_0 which indicated that MTIN pass and fail frequency distribution was closely related, was rejected.[4]

DISCUSSION

The objective of this study was to analyse the results for the National Board examinations for the periods 2008 to 2012 in the province of Gauteng S.A.

The investigations compared the following: the performances of MTIN from three of the provinces training laboratories; the performances of MTIN that qualified at three of the provinces HEI's prior to their Internship; the performances of MTIN in the four main disciplines and lastly the overall pass and fail rates for Clinical Pathology for the reviewed periods.

The performances of students that obtained their qualification at one of the selected three HEIs were compared. These compara-

tive studies were performed to investigate the statistical differences in the examination scores of MTIN related to the National board examinations for the four main disciplines. MTIN who came from University 1 achieved a higher score compared to those from University 2 and 3. Despite reaching a statistical significant difference the actual differences in mean scores between the three Universities was relatively small.

The highest mean performance score achieved in the National board examination by MTIN from these Universities was 53% for the periods 2008-2012. These low pass rates reflect poorly on the performance in the four main disciplines. HEI's have a profound and moral responsibility to increase both the skills and knowledge of SMTS to create a sustainable future for the profession. Further in-depth investigations are required to determine the reasons for the low pass rates. Issues such as matching the syllabus of HEI's and SMLTSA examinations; quality and standards of education at HEIs[8]; experience and qualifications of educators employed at HEIs, all need further investigation, in order to enhance quality.

Findings from an earlier qualitative survey study that involved: examiners and moderators of the National board examinations and the laboratory trainers overseeing the training of MTIN highlighted that improvement plans needed to be implemented urgently. These improvement plans would ensure that all SMTS received an adequate structured education and training at all HEIs throughout S.A.[8]

Four training laboratories that offered MTIN programmes were compared to each other related to the National board examinations results. The four main disciplines were again included in this comparison. Laboratory 4 achieved a higher score as compared to laboratory 2. Despite the statistical significance, the actual difference in mean scores between groups (lab 2 and 4) was quite small. The highest mean performance score achieved from all four laboratories was 52% for the periods 2008-2012. All four of these laboratories provided MTIN with induction and orientation programmes, rotation schedules through various required disciplines, discipline specific notes, formal lectures and formative assessments during the 12 months of the Internship period.

Various reasons accounting for these poor performances of MTIN from these training laboratories were *inter alia*: high staff turnover and lack of human resources; the adequacy and quality of training provided to MTIN; standard of training programmes, to name but a few.[8] Past research shows that there are two crucial areas that influence Internship training: the development of standardised outcome measures and training; and the evaluations for the assessment of MTIN readiness to write the National board examinations. It has been a known practice that MTIN that show inadequate performance have been deferred to the next available examination date. Further investigation into these area's is needed.[9]

The performances of MTIN in the four main disciplines was compared to evaluate the similarity of MTIN performance in each of these disciplines, as well as to investigate performance variation within a particular discipline. There are eleven different disciplines from which Interns can choose to write the National board examinations. The majority of MTIN choose to write one of the four main disciplines. However, approximately 80% of all Interns in SA choose to write Clinical Pathology. This is the most popular discipline and it provides qualified medical technologists with a wider opportunity to work in any of the following disciplines: Haematology, Chemical Pathology and Microbiology. This also increases the scope of the employable laboratory workforce in the diagnostic laboratories. It was concluded that there was no statistical significant difference in the performances scores for the four main disciplines and that the mean scores were equal.

It is general practice that MTIN are allowed to write the National Board examinations a maximum of four times, although no written policies to verify this are currently available on the HPCSA webpage. Using the Pearson Chi-square test it was indicated that during the period under review 59% of MTIN had to rewrite the Clinical Pathology examinations at least twice before passing. From the results obtained in this pilot study is clear that the ongoing poor pass rates are impacting on the future of the profession and immediate actions through proper investigations should be implemented to remedy the situation.

Limitations

This study was conducted in S.A. and only included one of nine provinces. Future studies should include all nine provinces and perhaps the SADC region as well.

Recommendation for future studies

Future statistical analysis could be performed to identify how MTIN perform in all eleven disciplines related to the National board examinations. An investigation into possible reasons for the high failure rates that were identified is recommended.[8]

CONCLUSION

No previous statistical analysis has been conducted on the performances of MTIN related to the board examinations and this unique study offers an invaluable insight into the ongoing poor pass rates and as such adds to the body of knowledge.

The statistical findings indicated overall poor performances for the National board examinations for MTIN for the periods 2008-2012. Approximately 59% of MTIN in S.A. repeated the Clinical Pathology examinations in that period. It is therefore suggested that an in depth investigation is urgently required to ascertain why MTIN keep on failing the National board examinations. Such an investigation should include reviewing the suitability of higher educational training at universities and also the adequacy of MTIN training offered by training laboratories, as these have a direct impact on the pass rates.

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REFERENCES

1. SMLTSA. [homepage on the internet]. Examinations Medical Technologists; c2016 [updated 2015; cited 2015 Aug 19] Available from: http://www.smltsa.org.za/examinations.html
2. HPCSA. Bridgemohan R. Chairperson's note. Medi Tech News [newsletter online]. 2015 Jan 30 [cited 2016 Jan 19];

2014/15:1-2,7. Available from: http://www.hpcsa.co.za/PBMedicalTechnology/Newsletter

3. HPCSA. Hind J. Supervision and liability of Interns and students. Medi Tech News [newsletter online]. 2012 Dec [cited 2015 Jan 30]; 2012:6. Available from: http://www.hpcsa.co.za/PBMedicalTechnology/Newsletter
4. Pallant P. A step by step guide to data analysis using IBM SPSS. SPPS Survival Manual. London: Berkshire; 2013.
5. Durrheim K. Numbers, hypotheses and conclusions. A course in Statistics for Social Sciences. Landsdown: UTC press, 2002; p.252-265.
6. Razali NM, Wah YB. Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. Journal of Statistical Modeling and Analytics Vol. 2011;2(1):21-33.
7. Cohen J. Statistical power analysis for the behavioural sciences. Hillside. NJ: Lawrence Earlbaum Associates. 1988.
8. Kruger W, Eagleton S, Maule WJ. Pilot study of Intern Medical Technologists performances related to the National Board examinations: views from the laboratory trainers, supervisors, examiners and moderators for the period 2008-2012. Medical Technology SA. 2016 Aug 22;30(1):5-9.
9. Sidlow R. The Structure and Content of the Medical Subinternship. J Gen Intern Med [serial on the internet]. 2001 [cited 2016 Feb 20]; 16(8):550-3. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1495247/