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Ordinal Regression Analysis of Students' Ability to Learn Statistics: A New Look At Operations Improvement for Statistics Education

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Abstract

An ordinal regression was conducted to set out the relationship between the students' ability to learn statistics and the explanatory key variables at the University of Cape Town (UCT) in South Africa. The data were randomly collected from 151 postgraduate students from UCT. The findings revealed that UCT had established an ordinal regression model using the logit link function as the best model. This work estimated that fear of statistics monitors, postgraduate programmes, engineering, health & wellness department were excellent predictors of Self-efficacy to Learn Statistics (SELS) beliefs. Additionally, the ethnic groups, marital status, postgraduate programmes, experiences in statistics and effort were significant contributing factors of SELS beliefs. The original value of this study is bridging the inequity gap, in statistics learning, and building a substantial input to the achievement of UNESCO, the World Education Forum and the White Paper 3 objectives. By extrapolation, it contributes to the sustainable development of learning statistics for other universities in South Africa.
***Keywords**: Statistics Understanding, Modelling, Confidence, Ordinal Regression Analysis.*

1. Introduction

According to [1], the education system reflects what the country values and holds dear. [2] acknowledge that statistics is a section of the mathematics programmes for secondary and primary school in various nations. Since quality learning of statistics is the critical factor, there is an urgent need to re-conceptualise how to prepare a generation of students, equipped to meet the demands of the 21st-century student [3]. The knowledge failure in statistics is a serious educational learning issue of students all over the world; its consequences have a dramatic effect on social, economic and innovation [4]. This situation raised many questions, which motivated the initiation of this current research. The principal research question is, therefore, "How can statistics learning orientate policies in South Africa are efficiently improved?" Many subsidiary questions are also raised; "What are the explanatory factors for the postgraduate students' low performance in statistics at UCT?" "What are the attempts made, or actions already implemented, to reduce statistics learning failure rate?" and "What are the current and future consequences of statistics learning failure, if more attention is not paid to the problem?" Due to the progress made in statistical techniques over the years, involving new statistics tasks, as well as the differences in students' academic backgrounds, the Self-efficacy to Learn Statistics (SELS) beliefs of students might also be different [5]. The lack of statistical knowledge and practical experiences lead to anxiety among postgraduate students (in terms of attitudes toward statistics, individual characteristics, social support, etc.) in their academic research ([6], [7]). There is a lack of an effective approach for students to follow, in order for them to gain a better understanding and interpretation (self-regulation) of statistical procedures [8]. Therefore, the poor performance of post-graduate students is differentially distributed among ethnic groups, and according to student status [9].

Urgent action is needed to address this specific problem for solutions, as the number of students with inadequate knowledge in statistics could decrease dramatically, if more effort is applied to reducing the grave differences between universities [10]. In South Africa, as in many African countries, the problem of statistics learning is a

major challenge for postgraduate students because of its complexity, lack of data and poor quality of existing data [11].

The primary focus of the study was the formulation of the ordinal regression model, the application of ordinal regression analysis, and the interpretation of study results. The students' SELS questionnaire was analyzed by the ordinal regression method to achieve the four study objectives:

To identify significant explanatory variables that influenced the overall students' SELS;

To estimate thresholds (i.e. constants) and regression coefficients;

To describe the direction of the relationship between the explanatory variables and the overall students' SELS based on the sign (+ and -) of regression coefficients; and

To perform classifications for all SELS levels of the overall students' experience, and subsequently evaluate the accuracy of the classification results.

The ultimate goal of the study was to make recommendations to enhance the awareness of the concepts, social support, statistics anxiety, and attitudes toward statistics as appropriate in the light of research findings.

2. Materials and Methods

The ordinal regression method was used to assess postgraduate students' abilities and confidence. The assessment was intended to be given to graduate students where instructors are not engaging students in statistical contexts. The assessment consisted of multiple choice questions addressing experience in research methodology and statistics, 99 likert questions addressing three sub-categories within statistics modelling interpretation and understanding [Statistics anxiety rating scale (STARS), Survey Attitudes toward Statistics (SATS), and Multidimensional Scale of Perceived Social Support (MSPSS)] and 14 Likert questions addressing student confidence about modelling in statistics learning within the four sub-categories. These assessments were piloted in multiple UCT campuses. Presented here is the development and theoretical framework for the assessment, focusing upon reliability and validity evidence with respect to measures of student understanding and student confidence following administration of the questionnaire. The outcome variable for students' ability and confidence to learn statistics was measured on an ordered, categorical six-point Likert scale. The major decisions involved in the model building for ordinal regression were deciding which explanatory variables should be included in the model and choosing the link function (e.g. logit link, probit link, cauchit link, negative log-log link and complementary log-log link) that demonstrated the model appropriateness. In addition, the model fitting statistics, the accuracy of the classification results and the validity of the model assumptions, e.g., parallel lines, were essentially assessed for selecting the best model.

Data were collected from a questionnaire which was distributed for a random sample of students at UCT from different departments. We received 151 of 200 questionnaires distributed. This study used the ordinal regression method to model the relationship between the ordinal outcome variable, i.e. different levels of students' self-efficacy to learn statistics (SELS) regarding the overall learning experience in the application of ability to learn statistics at the UCT, and the explanatory variables concerning demographics and students learning environment at UCT. The outcome variable for students' SELS was measured on an ordered, categorical, and six-point Likert scale (1. no confidence at all; 2. a little confidence; 3. a fair amount of confidence; 4. much confidence; 5. very much confidence; 6. complete confidence). It is implausible to assume the normality and homogeneity of variance for an ordered categorical outcome. Thus, the ordinal regression model becomes a preferable modeling tool that does not assume the normality and constant variance, but requires the assumption of parallel lines across all levels of the categorical outcome. Explanatory variables include gender, age, marital status, ethnic group, post-graduate program, student status, type of study, past experiences and 51 items related to the statistics anxiety rating scale, 36 items related to the survey of attitudes toward statistics, 12 items related to multidimensional scale of perceived social support at UCT. Regression methods such as linear, logistic, and ordinal regression are useful tools to analyze the relationship between multiple explanatory variables and students' SELS.

The ordinal regression method can allow researchers to identify explanatory variables related to statistics anxiety, attitudes toward statistics and social support, that contribute to the overall capacity of students to cope with the application of statistical procedures. The ordinal regression also permits researchers to estimate the magnitude of the effect of the explanatory variables on the outcome variable. The major decisions involved in the model building for ordinal regression were deciding which explanatory variables should be included in the model and choosing the link function (e.g. logit link, probit link, cauchit link and complementary log-log link) that demonstrated the model appropriateness. The study results could lead to a better understanding of the knowledge about statistics and services from students' perspectives ([6], [12]). The high internal consistency for the survey instrument might be demonstrated based on the alpha reliability. The reliability for SELS beliefs was reported as .980. Regarding the experiences component, the reliability of overall experiences indicated .820. Concerning the Statistics Anxiety Rating Scale (STARS) instrument, the rationality indication of STARS to

other variables was .962. The Cronbach's Alpha coefficient was reported reliable as .876 for the SATS. Cronbach's Alpha coefficients reported as .929 for the social support.

3. Results and Discussion

In this current study, the ordinal regression method was used to model the relationship between the ordinal outcome variable, for example, the different levels of students' SELS, in terms of the application of statistical procedures in their academic work, as well as the explanatory variables concerning demographics, experiences, emotion, behaviour and environment factors. The outcome variable for students' ability was an ordinal response variable, measured on an ordered way. The main choices taken in the model structure for "ordinal regression" were, determining which explanatory factors to include in the model, as well as selecting the link meaning that established the model suitability. It is unbearable to accept the normality and homogeneity of the adjustment for well-organized categorical outcome. The investigation of the distribution of values for SELS beliefs enables students to choose the relevant link function that provides the most suitable fit for the data. The histogram for the dependent variables illustrates that the outcomes are consistently distributed in categories (see Fig. 1). Therefore, the logit link function is applied to ensure that the distribution of outcomes is reliable.

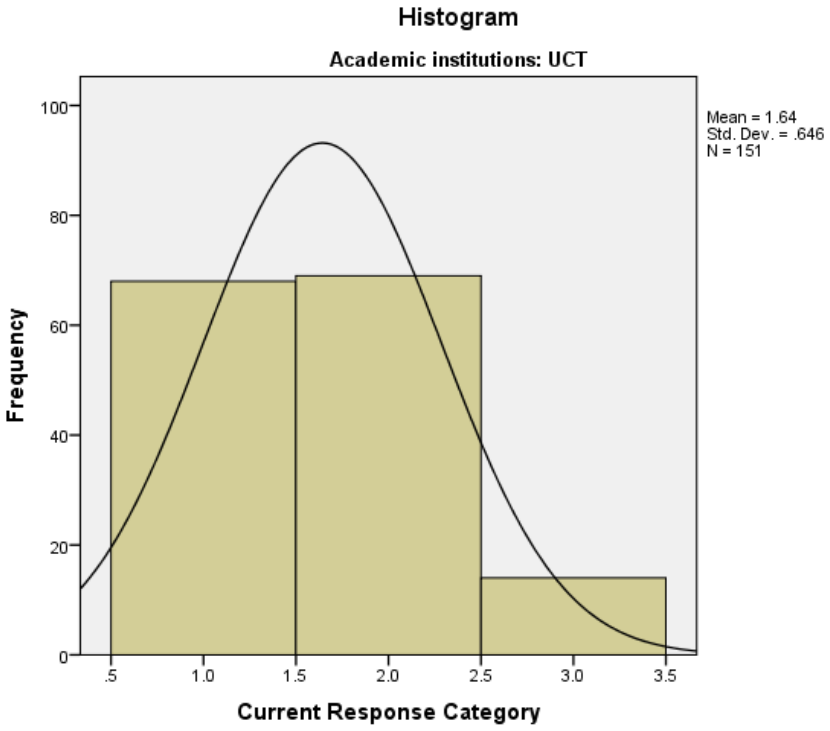

Fig. 1 Distribution of students' overall self-efficacy to learn statistics at UCT

3.1 Predictive value of the model

The complete model, using the Logit Link function, examined 100 of the 151 questionnaires, and excluded 51 questionnaires from the study, due to the existence of at least one item with missing data, or 'not applicable' rating. The complete model, containing all the factors and co-variates (items), revealed a number of interesting findings. The difference between the two log-likelihoods revealed significant chi-square statistics.

Table 1: Model-fitting information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	186.649			
Final	123.009	63.640	31	.000

Link function: Logit

Therefore, the model fitting information indicated a significant improvement over the baseline intercept-only model, with p = .000 (See Table 1). The predictions were suited, rather than assumed, based on the probabilities for the outcome categories.

3.2 Test of parallel lines

The assumption was that the slope coefficients were approximately the same for all response categories. The findings confirmed that there was not sufficient evidence to reject the parallelism hypothesis. Therefore, the observed significance level in Table 2 was large (p= .788, greater than .05). An ordering that places "little confidence" as a greater value may have a better fit.

Table 2: Test of parallel lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	123.009			
General	98.474[b]	24.535[c]	31	.788

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.
b. The log-likelihood value cannot be further increased after maximum number of step-halving.
c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.

3.3 Pseudo R-squared measures

Some approximations are computed as a replacement for the coefficient of determination, R2 [13]. These approximations (pseudo R-squareds) are described in Table 3. Based on this standard, Nagelkerke/Cragg and Uhler's study achieved the highest report, with 55.7%, followed by Cox and Snell with 47.1%, and McFadden, who reported the smallest approximation of 34.1% ([14]; [13]).

Table 3: Pseudo R-squared measures

Nagelkerke/Cragg and Uhler	.557
Cox and Snell	.471
McFadden	.341

Link function: Logit

The best fitting model is the model with the largest statistics. In Table 3, the approximation of Nagelkerke/Cragg and Uhler (R2) was the best, with 56%.

3.4 Classification table

This section focuses on the assessment of ordered response variables, since whether or not the ordering is relevant for the regression relationship, is significant. A confusion matrix in Table 4 describes the cross-tabulation of the expected groups with the actual groups. The model with the logit link accurately predicts the outcomes categories as follows: category 1: 75.6%, category 2: 78.3% and category 3: 33.3%. The models appropriately complete a high prediction accuracy of 73% for all three categories combined.

Table 4: Confusion matrix for the initial model

Current response Categories		Predicted Response Categories			Total
		A little confidence	A fair amount of confidence	Much confidence	
A little confidence	n	34	10	1	45
	% within Current Response Category	75.6%	22.2%	2.2%	100.0%
A fair amount of confidence	n	8	36	2	46
	% within Current Response Category	17.4%	78.3%	4.3%	100.0%
Much confidence	n	1	5	3	9
	% within Current Response Category	11.1%	55.6%	33.30%	100.00%
Total	N	43	51	6	100
	% within Current Response Category	43.0%	51.0%	6.0%	100.00%

3.5 Interpreting the model

Evaluating the complete model with the logit link revealed that the two thresholds of the model equation were significantly different from zero, and substantially contributed to the values of the response probability in different categories. In addition, the overall SELS was significantly associated with the four explanatory variables, namely, fear of statistics teacher, postgraduate programmes, engineering department and health & wellness department. Except for the fear of statistics teacher, these significant explanatory variables revealed positive regression coefficients, indicating that students, who scored higher levels of satisfaction on these explanatory variables, were likely to be rated at a higher level for the overall SELS. In the same manner, the students who scored lower levels of fulfilment on these descriptive variables, were probable to be rated at a lower level for the overall SELS beliefs. Table 5 shows that of these four approval items on the overall SELS beliefs, 75% or 3 satisfaction items were related to academic factors (postgraduate programmes, engineering department, health & wellness department). In addition, 25 percent or 1 item was related to emotion factors (fear of statistics monitors).

Table 5: Parameter estimates

Item names	R. coeff.	P-value		Item names	R. coeff.	P-value
[SelfEffAbsMeanOrd = 1]	5.185	.041		Marital status	.434	.523
[SelfEffAbsMeanOrd = 2]	9.231	.001		Postgraduate prog.	2.001	.003
Experiences in Stats	-.505	.218		Student status=0	-.072	.941
Test factor	-.182	.703		Student status=1	-.725	.463
Interpretation factor	.575	.389		gender	1.006	.218
Ask for help factor	-.884	.146		Type of study	.951	.517
Self-concept factor	.565	.288		Applied Science=1	-16.243	.998
Teacher factor	-1.109	.045		Bus & Manag=2	2.249	.225
Affect factor	.949	.065		Education=3	3.278	.289
Cognitive compet.	-.878	.164		Engineering=4	7.364	.001

Item names	R. coeff.	P-value		Item names	R. coeff.	P-value
Value factor	-.876	.065		Health& wellness=5	3.612	.035
Interest factor	-.144	.739		Art & humanity=7	1.280	.420
Effort	-.770	.090		EMS	3.071	.084
Support- Others	-.283	.519		Natural science=10	2.719	.067
Family support	-.466	.320		Law =11	2.456	.103
Friend support	.103	.804				

The significance of the test for postgraduate programmes was less than .05 (p = .003), signifying that its experiential effect was not due to coincidental. Since its coefficient was confident, as postgraduate programmes increase, so does the likelihood of being in one of the groups of the overall SELS beliefs. In addition, the engineering department displayed a significance in the test with P = .001, indicating that the overall SELS beliefs was associated with the engineering department explanation. Therefore, being a student from engineering department explained the effect of variation observed in the overall SELS beliefs, and as engineering department increases, the probability of being in one of the categories of the overall self-efficacy to learn statistics increases, as well. Similarly, the health and wellness department was statistically significant with p = .035. Its coefficient was positive, revealing that the change observed in the overall SELS beliefs was associated with the change in the health and wellness department. This means health and wellness department decreases, or increases, simultaneously, with the probability of being in one category of the overall SELS beliefs. However, the fear of statistics teachers factor was only slightly significant (p = .045). It contributed meaningfully in the model with a negative coefficient, revealing an inverse direction in the improvement of factors. Students with high levels of "fear of statistics" teachers were related with low level of SELS beliefs. None of the items regarding behaviour, social support, prior knowledge and socio-demographic factors was significantly associated with the overall SELS beliefs. However, the minor effects of each category of these items accumulated and provided useful information to the model.

3.6 Predictive value of the model using Cauchit Link function

Comparable to linear and logistic regression modelling procedures, the principle of meanness, was appropriate to the building of the best "ordinal regression" model [13]. In this sense, the complete model, using the Cauchit Link function, investigated 101 of the 151 questionnaires, and excepted 50 questionnaires from the study, due to the existence of at least one question with missing information, or 'not applicable' score.

Table 6: Model-fitting information

Model	*-2 Log Likelihood*	*Chi-Square*	*df*	*Sig.*
Intercept Only	188.191			
Final	120.594	67.596	30	.000

Link function: Cauchit

In Table 6, the researcher provides an illustration that the model afforded appropriate predictions. The difference between the two log-likelihoods was significant. Therefore, the model fitting revealed a substantial improvement over the reference point intercept-only model with $\chi 2 = 67.596$, a d.f. of 30 and p = .000.

3.7 Pseudo R-squared measures

Three pseudo R-squared measures are presented in Table 7, revealing that the model with Cauchit Link fits the outcome data. Nagelkerke/Cragg and Uhler's displayed the best measure (58%), followed by Cox and Snell's (49%), with McFadden's (36%), the smallest ([15]; [13]). According to the standard, Cox & Snell's pseudo R-squared measure has an extreme value of less than one, while Nagelkerke/Cragg & Uhler's R-squared measure

is the complete model that perfectly predicts the result and has a probability of 1. However, the highest pseudo R-squared measure represents the best model to estimate the effect.

Table 7: Pseudo R^2

Cox and Snell	.488
Nagelkerke/Cragg and Uhler	.578
McFadden	.359

Link function: Cauchit

3.8 Test of parallel lines

The full model with the Cauchit link is unsuccessful to deliver the indication of sustaining "parallel lines" statement (see Table 8), implying that meeting could not be extended according to the SPSS printout; therefore, the research discoveries stated above are needless. Therefore, it is preventable to prepare a table that contains item name, regression coefficient, and p-value in this sub-section.

Table 8: Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	120.594			
General	154.710[b]	.[c]	30	

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Cauchit.
b. The log-likelihood value cannot be further increased after maximum number of step-halving.
c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.

There is no specific technique to determine the favorite of using different link functions. The model with the Cauchit Link function has definite limitations. Despite the circumstance that the model suitable information was significant ($\chi 2 = 67.596$ with d.f. of 30 and $p = .000$), the table of pseudo R2 displayed higher values in the three measures, specifically, McFadden (35.9%), Cox and Snell (48.8%) and Nagelkerke/Cragg and Uhler (57.8%). In addition, the model with the Cauchit Link function was not particularly reliable, and was unable to assist in estimating the general model. Consequently, the model with the Logit Link function produced good fits for the data, and was generally appropriate for analysing the ordered categorical data, evenly dispersed between all categories.

3.9. Correlation estimated classification probability between predicted and actual category

A further investigation of the model with the Logit Link function was conducted, as it was the best model. A "Spearman's rho correlation" coefficient was applied to investigate the association between the predicted and actual category. A strong positive correlation of the estimated classification probability between predicted and actual category, $rho = .709$, $p < .000$, $n = 100$ is illustrated in Table 9.

High levels of estimated classification probability for a predicted category are associated with high levels of estimated classification probability for the actual category. The strength of the relationship represented 50.27%. The estimated classification probability for the predicted category may explain the 50.27% in the variance of the estimated classification probability for the actual category, which is remarkable. A positive correlation coefficient implies that a high increase in predicted category is connected with high upsurge in actual category, and vice versa.

Table 9: Correlation between predicted and actual category

			Estimated Classification Probability for the Predicted Category	Estimated Classification Probability for the Actual Category
Spearman's rho	Estimated Classification Probability for the Predicted Category	Correlation Coefficient	1.000	.709**
		Sig. (2-tailed)		.000
		N	100	100
	Estimated Classification Probability for the Actual Category	Correlation Coefficient	.709**	1.000
		Sig. (2-tailed)	.000	
		N	100	100

** Correlation is significant at the 0.01 level (2-tailed)

The quantitative analyses were based on three main steps: the descriptive analysis of components obtained from the quantitative questionnaire; the bivariate analysis with cross-tabulations; and the multivariate level analysis with ordinal regression models, using Logit and Cauchit link functions. These models rely on the assumed probability distributions of the continuous variables (dependent). All these steps were performed using the UCT data. In fact, the bivariate analysis focuses more on the impact of the independent variables on the SELS beliefs. The results of the bivariate analysis highlighted the STASTATS and STARS, experiences in research methodology, as well as experiences in statistics, while the effort were statistically significantly different in the means scores of SELS beliefs for the groups.

However, the multivariate level of analysis provides more statistically substantial results because of the control in the model, therefore, it is important to focus the summary on these results. The ordinal regression undertaken revealed that the independent variables predicted the level of SELS beliefs, significantly. These results constituted an important finding of this study. The outcomes of the ordinal regression, using the Logit link function was the best model, indicating that the postgraduate programmes in the engineering department, health & wellness department, as well as fear of statistics monitors, were the significant predictors of SELS beliefs.

4. Discussion of the findings at UCT

4.1. Discussions

The assessment of the quantitative results is elaborated under three sub-headings, namely, the descriptive analysis, the impact of the predictors of SELS beliefs, and the evaluation of the multivariate analysis. For the UCT, the evaluation of the impact of the predictors of self-efficacy to learn statistics beliefs (SELS beliefs) attempted to respond the subsequent study questions: What are the effects of the individual characteristics, emotion, behaviour and social support on the SELS beliefs at the UCT? In this current study, the researcher aimed to investigate the associations of SELS beliefs, background and academic variables, prior experiences, statistical anxiety, attitudes towards statistics and social support.

More than 60% of the postgraduate students scored the highest category in experiences in research methodology. Experiences in research methodology presented a statistically important means change in the groups, with a moderate effect size, $F(2, 148) = 4.769$, $p = .010$. There was a positive association between SELS beliefs and experiences in research methodology of the graduate students. The positive association is similar with [16] conclusions. The respondents achieved the highest scores in the experiences in research methodology subscales, indicating the graduate students' enthusiasm and fervour for a positive confidence in the implementation and resolution of statistics. General, these outcomes, as well as the positive association between SELS beliefs and experiences in research methodology, seemed to describe a kind of self-assurance expectation that postgraduate students undertake, when compelling statistics. Postgraduate students, who may experience under stress to seem publicly wanted, may under-record their levels of statistics anxiety, as well as over-record their levels of performance, which is similar to [17] findings.

Regarding experiences gained in statistics, 43.7% achieved the Good level. However, only a miniscule percentage (.7%) of the postgraduate students scored Very bad in experiences gained in statistics. Those who scored Average in experiences gained in statistics were 39.7%. The means score achieved in experience gained

in statistics was good (3.6), F (2, 148) = 3.478, p = .033. Experiences gained in statistics revealed a statistically substantial means variance in the categories with small effect size. A positive association was established between SELS beliefs and experiences gained in statistics. These outcomes designated that, when the graduate students' experiences gained in statistics increased, their SELS beliefs were higher. The results indicated a better response to experiences gained in statistics, not generated in other researches, where students were presenting with undesirable experiences in statistics [6]. Remarkably, the postgraduate students in this current research were average in their ability to learn statistics, lacking great feedbacks.

The majority of the respondents indicated a low anxiety in STASTATS (statements related to statistics). In addition, the findings of an "independent samples t-test" exposed that the mean difference = .887, t (149) = 3.202, p = .002, two-tailed. There was a statistically significant negative association between the SELS beliefs and STASTATS of the postgraduate students, with moderate effect size (eta squared = .06). The negative association is coherent with [16] outcomes. The respondents achieved their lowest responses in the STASTATS, revealing the postgraduate students' willingness to asking for help from the supervisors and monitors, their slight belief in the solving of real world problems, as well as the purpose of statistics. [18] claim that possessing a good background in statistics does not ensure good performance. Generally, these results, as well as the negative association between SELS beliefs and STASTATS anxiety created the impression of a self-prediction that postgraduate students adopt, when taking statistics. However, the actual findings were not consistent, and completely different to the [19] report, where more than half of the respondents obtained high anxiety. Therefore, the lower STASTATS anxiety of the postgraduate students towards statistics is associated with higher SELS beliefs.

Similarly, the respondents reported a low level of STARS anxiety (overall statistical anxiety), which indicated that most of the postgraduate students believed that they were not anxious, and had a better knowledge of statistics. Additionally, a statistically significant association was established between SELS beliefs and STARS anxiety, with a moderate effect size (eta squared = .08), mean difference = .828, t (149) = 3.615, p = .000, two tailed. The respondents perceived STARS anxiety as a leading issue in their existence, which is comparable to [18] report, where second year students, who scored higher on the statistics, revealed lower anxiety on the STARS scale. Poor communications between the instructors and the students might be one of the reasons for statistics anxiety. Students are encouraged to relay their most important questions to statistics monitors, or peers. However, STARS anxiety was a statistically important interpreter of SELS beliefs.

Regarding the SATS, a shortcoming must be highlighted about the general attitude assessment. Only effort indicated a statistically noteworthy means modification in the sets, with a large effect size. Though, it was observed that, about, 70.9% of the respondents showed a high positive SATS, which is alike to previous results [6]. Effort revealed the prominence of the postgraduate students' determination in their capability of resolving the challenges of learning statistics. Therefore, F (2, 148) = 10.936, p = .000. Also the clear constraint for supervisors to guide the statistics subject, it may be vital to discuss the importance of statistics, how it is relevant to the research, as well as its expectations in graduate programmes. The experiences gained in statistics and exposure to empowerment (effort), as well as type of study are not favoured by postgraduate students from the Art & Humanity, as well as Law departments. Apparently, students from these departments mostly achieved lower levels of confidence in SELS beliefs, compared to those from other departments. In a poor context, such as the Law department, where more than 98% of the students achieved under the bottom line in SELS beliefs, with a little confidence, the influence of the effort status is quite evident. The results of the multivariate analysis revealed that students with bad experiences in statistics have 5 times more apprehension of SELS beliefs, than those, who performed well. In fact, bad scores indicate a lack of confidence, which, therefore, is challenging during or after graduate programmes. The professors, or statistics monitors could enact a main character in influencing their students' SATS, positively. Inserting humour, showing compassion, supplying a confident environment for students to exchange about their tests, and rejoicing their minor achievements, are be tools that could be employed to combat negative attitudes.

However, there was no change in the association between academic, demographic and SELS beliefs; therefore, each of them was not a contributing variable. Similarly, SATS and social support factors were not statistically significant in means difference among the groups. SELS beliefs scores from the respondents designated moderate responses, which reflected previous experiences, connecting undergraduate students [20]. As this current study was the first in this context to investigate postgraduate students, these outcomes making a track for upcoming study.

What are the factors that significantly predict student's SELS beliefs at the UCT?

The evaluation of the results of ordinal regression to build a model with the UCT data, using Logit link function, revealed that the "fear of statistics" monitors, postgraduate programmes, engineering department and health & wellness department were the significant determinants of SELS beliefs, among the predictors selected for the

analyses. In fact, the multivariate analysis of the UCT data indicated a positive effect of the postgraduate programmes, engineering department and health & wellness department on SELS beliefs. In addition, the postgraduate programmes affected the traditional beliefs and the daily practices of student learning in diverse social and economic ways. The postgraduate programmes' practices and norms could determine the student's educational and learning style exposure to a certain degree, the attraction to a specific department or another, practices regarding support, choices of consultation for assistance, such as asking for help (supervisors or peers). However, the influence of the postgraduate programmes also depended on the type of study, test factor and interpretation factor. In sum, these results proved that masters' students from Engineering or Health & Wellness were more responsive to SELS beliefs, than the other abovementioned, because of some practices regarding their experiences in statistics, marital status, type of study, their empowerment and supports.

The univariate analysis performed on UCT's data revealed that 62.8% of the postgraduate students were in master's programmes, while 37.2% represented those in PhD/post-doctorate programmes. Despite the number of students engaged in postgraduate programmes, there was no major modification in the means scores of SELS beliefs, regarding postgraduate programmes.

However, the findings from multivariate analysis revealed that postgraduate programmes were a contributing factor in the model (RC = 2.001, p = .003). Master's students were encouraged to engage in postgraduate programmes. These studies are very important for the detection of possible problems. Statistics are important in graduate programmes, and UCT has made efforts (tutoring, assistance by peers), at the department level, to improve their students' knowledge. In cases of difficulty, this action will assist students to overcome their relevant challenges.

The results revealed that when emotion ("fear of statistics monitors") increases, the possibility of SELS beliefs decreases. In addition, the results revealed that "fear of statistics" monitors was a statistically important prognosticator of SELS beliefs. This was a key result that emerged from the stepwise Ordinal Regression Model. In brief, "fear of statistics" monitors only decreased the chances of SELS beliefs among graduate students at UCT. The univariate analysis highlighted that 83.4% of the postgraduate students presented with low anxiety for the "fear of statistics" monitors, compared to 4% with high anxiety, while 12.6% presented with moderate anxiety. Though, a major mean variance was observed between the "fear of statistics" monitors groups. The findings of the multivariate analysis confirmed that it significantly contributed to the prediction of SELS beliefs (RC = -1.109, p = .045). Obviously, students with less anxiety probably maintained higher confidence levels in SELS beliefs.

The findings about poor communications between students and statistics monitors seemed to concur with a previous study, conducted by [21], with two universities in Northern Ireland, where undergraduate students appreciated their awareness of statistics. Easy communications between supervisors and students could be a possible reason. Among others, the STARS questionnaire is self-reported, and some postgraduate students, who may be under stress to seem publicly wanted, may tend to overestimate their emotion.

All the instruments applied in this research allowed for self-reporting and, consequently, exposed to subjective preference. This disproportionate representation of students' emotion revealed a need for intervention, to improve their attitude, and overcome their fear of statistics. Similarly, the findings of [22], regarding the application of the statistical perceptions to enlighten real-life difficulties, provided graduate students with occasions to strengthen their knowledge.

The respondents showed that "fear of failure" was one of the sources of anxiety. In addition, the "fear of statistics" monitors', revealed that the contributing factors might be varied, from math phobia, misunderstanding belief around statistics, to the instructors' attitude about the absence of linking to tangible difficulties. If the instructors were more sensitive to the students' challenges, it would be likely to assist postgraduate students in academia to study statistics more efficiently. Addressing their anxiety and supplying handling approaches to the students, were suggested in the literature [22], as active practices for the reduction of STARS.

The findings of the univariate and multivariate analyses of UCT's data, using the Logit function, highlighted the Engineering and Health & Wellness departments as important significant factors of SELS beliefs. In fact, both analyses proved that these departments were more capable of SELS beliefs, than any other department was. Indeed, students from the Engineering department were, at least, 30% more proficient at SELS beliefs, than those students were in the Art & Humanity, as well as Law departments. The risk of not possessing SELS beliefs reduces with the engineering department. A lower risk was observed among Engineering students (Regression coefficient = 7.364, p = .001), followed by students from Health & Wellness (RC = 3.612, p = .035). The research findings concerning Sciences departments in this study appeared to be similar to a preceding study conducted by the South-Western University in the USA [17], where graduate students strongly valued their learning environment.

This current study's results could be important for policy makers and planners, because the youth (students), considered as the future of a country, are the most vulnerable regarding learning statistics. It may be important for students to know why statistics must be knowledgeable, in what way it is appropriate to the chosen major of graduates, and what potentials in graduate schools may be. More engineering students had an improved

appreciation of the significance of statistics for their prospective professions. Centred on the reactions, this may be connected to the illustrations done in the class. For instance, students in Health & Wellness may use medication sales data to demonstrate a point, or possibly carry out investigations, and suggest explanations. Psychology, as an example, may provide a dissimilar method. The bulk of Psychology majors are naturally concerned in direct services, which are often in the areas of clinical or counselling psychology. Most of the Psychology lecturers, who explain statistics, are probably from non-clinical experiences. It may be that the cases applied by these lecturers could be related to their area of interest, than the benefit of the students.

The Law students may follow vocations that are more service oriented. As such, they may observe their forthcoming service in areas of audition, parole, prisons, juvenile justice, and others, as fields that will not require them to be great consumers of statistics. One method might be to decide the imminent vocation ideas of students and supply cases that would be fitting in those conditions. Nonetheless of how this is to be applied, lecturers of Psychology and Criminal law surely have much progress to make, in order to supply students with more evidence on how statistics will be pertinent to their coming works.

However, similar results were found with some researchers, who had inspected attitudes toward statistics within one discipline, and have recommended appraisal across majors [23]. scrutinised the variances in a business school. Evaluations were conducted among undergraduate students from Accounting, Taxation, and Marketing. It was found that Taxation majors had more undesirable attitudes toward statistics, than the other two groups. Because of the prominence of statistics, as a compulsory course through diverse disciplines, as well as the limited amount of research comparing different majors, such contrasts may produce exciting outcomes, and expose diverse patterns through many disciplines, which could be used to improve statistics courses, for students of a given major.

The statistics monitors can play a significant role in positively influencing their students' attitude toward the subject. Adding humour, demonstrating empathy, developing a safe space for students to talk about their tests, and initiating small success celebrations of students can enhance positive attitudes. On occasion, the consultations with the students do not reveal any problems, and the students discontinue the assistance (supervisors or peers). In addition, occasionally they do not have the means to continue the academic programme, or maybe they do not have necessary financial means to access all the facilities; therefore, they seek more cost-effective alternatives outside the academic system. This is generally more commonly found among poorer students, and those from rural areas; however, it could also occur among students from urban areas [24]. In fact, some beliefs related to customs or traditions are the reasons why some women abandon educational programmes, because of misperception or mystification. However, it is also evident in literature that many students from disadvantaged areas, or females, are not able to deal with mathematics issues; therefore, they tend to give up easily when complications arise, or after the failure in task execution [25].

In a context where the entire population is dominated by youth, with a minority of elders, the urgency of the issue becomes patently clear. Helping graduate students to choose a positive view to explore essentially negative attitudes, and to appreciate the usefulness of statistics in their profession, may be good starting points for developing salient attitudes towards the statistics.

4.2. Strengths and limitations of ordinal regression in this current study

This study presents a brief explanation of the assets of the ordinal regression model. Various variables of learning statistics outcomes are on a Likert scale. Therefore, the ordinal regression model tends to perform diverse student learning outcomes.

Alike to the regression models, the ordinal regression model is designed firstly to find significant explanatory variables that impact the dependent variable; secondly to designate the trend of the connection between the descriptive variables and the ordinal outcome; and thirdly to complete categorisation for all levels of the SELS beliefs, and after assess the strength prediction of the regression model [6];

Logit, Cauchit, Probit, Negative log-log and Complementary log-log links enable to perform the consequence of the predictors on the dependent variable. The examination of matching shapes measure the rationality of the model supposition, and the model suitable measurements, for instance, the -2log likelihood ratio and pseudo R squares are considered as measures to monitor the aspirant models, and select the best model.

Lastly, the model adopts that the association among the independent attributes and the dependent variable is not taken in account the group. This supposition infers that the consistent regression coefficients in the relation meaning are equal for each group. Therefore, it is simple to concept and understand the ordinal regression model, which requires only one model assumption, and produces only one set of regression coefficients.

However, the application of the ordinal regression model reveals some limitations. For instance, the not applicable responses of independent attributes are considered as absent values and omitted from the investigation. A huge percentage of cells with absent data, tend to reduce the real sample magnitude for the model building, or an incorrect "chi-square test" for the suitable model. Bear in mind that the adjusted model's quality is generally reliant on the "chi-square test" outcome, which it is hang on the sample magnitude. [26]

acknowledges that a huge amount of cells with a zero value influence the suitability of the chi-squared goodness of fit statistics. This context limits the researchers' ability to measure the model's goodness of fit successfully. Furthermore, the logit, probit, cauchit, negative log-log and the complementary log-log link in the ordinal regression analysis cannot select a subgroup of important descriptive attributes, via unconscious model construction procedures, for example stepwise and spinal removal procedures in SPSS knowledge linguistic. Consequently, investigators are pleased to trust their individual perception and understandings, to choose a set of the important independent attributes in the model. Based on that, considerable time and vitality is engaged to emerging aspirant models, examination of the model conventions, and guaranteeing the adjusted model's quality.

4.3. Limitations of Likert-Type Scales on using and learning statistics

The main objective of learning statistics is to encourage a positive attitude toward statistics and its practices in students, as well as to develop their self-assurance. Therefore, the evaluation of the ability of actual instruments to investigate variations in students' with such problems is significant. In contrast, the students' aspects being measured, such as emotion, behaviour, social support ratings or SELS beliefs may be easily altered, and possible to oscillate, reliant on varying conditions and actions. Consequently, when interpreting the score changes, the expected stability of the constructs being measured, need to be considered, over time. However, studies using statistics emotion, behaviour and social support surveys regularly describe relationship information, or mean ratings' variations, but not absolute rating stages. Such information, while investigating the presence of associations among emotion cuts and the dependent variable, generate inadequate evidence about the type of that variable which is varying over time.

Statistical researchers compute absolute scores, by adding these scores to any other statistical facts, the inferences do not reflect the true facts evaluated. Described average rating variations, can be of incomplete amount, if they are not aggregate by information around tendencies of learning implication, for example the percentage of students whose ratings remained the unchanged, upgraded (additional constructive attitudes), or deteriorated (additional undesirable attitudes). Definitely, similar statistics are disguised once a particular statistic is planned on an entire illustration. Instruments such as the STARS, SATS, SELS and MSPSS produce ratings that are simply reportable, and are suitable to practice for an extensive explanation of the results of learning statistics. Such questionnaires cannot provide indicative evidence that can reveal to specific problems of anxiety for students; so, the present instruments of STARS, SATS, MSPSS and SELS have very inadequate competence to update about the improvement procedure, content of learning statistics via corrective and preventive measures.

Likert scales' responses expose little around the reasons for the respondents' answers, regarding emotion for instance, which may affect the students' attention, inspiration, and understanding, negatively. Therefore, it seems that the usefulness of Likert-type scales are incomplete, in terms of investigating whatever students are worried, their behaviours about statistics learning, as well as what categories of social support, or educational practices might be valuable for students. This important lack in the design of scales to measure students' emotions, social support and behaviours towards mathematics, lead researchers to consider semi-structured interviews, or request students to write pasts, of their current, or past, mathematical practises. The objective is to increase a nearer look on the previous educational experiences causing negative attitude on students' learning in numerical fields. In addition, some problems severely limit the interpretation of the achieved scores, at both individual, and group levels. These problems are, the tendency of not seeking descriptions from the themes for their responses, the practice of using total scores, and the distraction to the associations between attitudes towards statistics and other concepts, when understanding outcomes.

The significant improvement completed by instructors, in illustrating the changes between attitudes, beliefs and emotions, as well as between these and other connected concepts, such as social support, or self-efficacy [27], might produce an exceptional preliminary fact for statistics instructors, looking for to understand the issues that affect their students' achievement and learning. Development in understanding the role of some problems and their effects on statistics learning should be reinforced from two diverse, but connected guidelines. In one hand, the assessment of students' attitudes toward statistics should be improved, so that the sense, the reduction of anxiety, or negative approaches can be understood. Second, the collaboration among these undesirable approaches and students' emotions about themselves and field of study should be explored. Additionally, the expansion of evaluation instruments, to provide appropriate information of both conceptual and methodological, includes many challenges.

5. Conclusions and policy recommendations

5.1. Conclusions

Statistics learning is one of the most important issues of statistics education today. International consciousness about the problem was manifested in the inclusion of statistics learning as one of the targets of the statistics education. Unfortunately, insufficient research has been conducted on the subject. Estimates of statistics learning levels are rare, controversial and sometimes contradictory. There is a great need to estimate the level, follow the structural change in the students' SELS beliefs, and scientific explanations of the immediate, and distant causes of failure in statistics learning. The situation is worse in developing countries, where the HES does not operate smoothly. The poor quality of existing data, as well as the lack of information about statistics learning, should not restrict researchers from providing answers to these problems. On the contrary, it is an encouragement, and an appeal for scientific investigation on the issue, to provide guidance, as well as make full use of the findings. It is acknowledged that achieving a superior standard of HES, is not for the short- or medium term, in developing countries, as South Africa; however, this solution remains the best, in order to provide adequate data regarding statistics learning. This is an additional argument, in favour of initiating research on the subject, without waiting for the availability of perfect data.

Given the disparities in knowledge about this issue, the researcher in this current research set out to examine the connection between the postgraduate students' SELS beliefs, STARS, SATS, and social support. Four objectives were assigned to the research. To reach the objectives of the study, quantitative data was used for UCT. The findings at bivariate levels could be biased, because of hidden factors; therefore, advanced analyses, based on the multivariate model, were conducted to achieve the objectives of the study. These results are highlighted and detailed in the findings, resulting from the analyses of the specific research questions of the research.

The results of the main objectives are summarized below, according to the specific research questions:

What is the graduate student's experience level in statistics, and research methodology?

The overall descriptive results revealed that the graduate student's experience level in research methodology was average, and in statistics, it was good. The graduate students were well prepared in statistics, compared to research methodology.

What is the graduate student's statistics anxiety level?

In general, the graduate student's statistics anxiety level was low, except the "Test and class" anxiety component, which was moderate. The rest of the statistics anxiety components were low.

What is the graduate student's attitude toward statistics?

Concerning attitudes toward statistics, the students achieved a moderate level. In fact, two of the six components, "interest" and "effort", indicated a high level, the rest of the components were moderate.

What is the graduate student's level of perceived social support?

According to the overall perceived social support, the graduate students achieved a mildly agree level; however, the support from "family members" realised a strongly agree level.

What is the graduate student's self-efficacy level?

In general, the current self-efficacy (self-efficacy to solve) for the graduate student's level indicated much confidence. However, one of the five components, vicarious, indicated very much confidence at the lower boundary. Concerning the expected self-efficacy (self-efficacy to learn), students realised very much confidence in all the components, given that the absolute difference between the current and expected self-efficacy, provided SELS, the ability to learn statistics [28]. The difference was modest in the respondent's factual, conceptual and procedural understanding.

What are the effects of the individual's characteristics, experiences, emotion, behaviour and social support on the SELS beliefs at the UCT?

Among the academic and demographic characteristics applied, no statistically significant difference was found in their means. The findings revealed that both experiences in statistics and in research methodology were statistically significant different in the means scores of the students. These experiences contributed positively to the graduate students' ability to learn statistics. More students with good in experiences tended to be more confident in SELS beliefs.

Regarding statistics anxiety, statements related to statistics (STASTATS) and the overall component of statistics anxiety (STARS) displayed a statistically significant difference in the means scores of the students. These variables negatively influenced their ability to learn statistics. For attitudes towards statistics components, only effort displayed a statistically significant difference in the means scores. The more effort the students exercised, the more they increased their ability to learn statistics. As for social support variables, no statistically significant results were found.

What are the factors that significantly predict SELS beliefs at the UCT?

The SELS beliefs were significantly related to four variables, namely, “fear of statistics” monitors, postgraduate programmes, engineering department, as well as health & wellness department. The academic variables revealed positive regression coefficients, indicating that students, who scored higher levels of satisfaction for these explanatory variables, were likely to achieve a higher level of SELS beliefs. Additionally, the students, who scored lower levels of fulfilment for these predicted variables, were likely to attain a lower level of SELS beliefs. Of these four predicted variables on the SELS beliefs, 75% or 3 variables were related to academic factors (postgraduate programmes, engineering department, as well as health & wellness department). Only 25 percent or 1 variable was related to emotion factors (fear of statistics teacher). In fact, students were encouraged to attend a minimum of consultations with statistics monitors, or peers. Unfortunately, many PhD/post-doctorate students did not ask for help, because they wanted to portray a standard of knowledge that they did not really possess, in order to preserve a fictitious personality. Similarly, further analysis revealed that the influence of belonging to a particular department, explained the importance of how experiences in research methodology and experiences in statistics acquired over years, enhanced the SELS beliefs levels of students. This best ordinal regression model at UCT appropriately completed 73% of prediction accuracy, for all three categories combined, which was quite high.

5.2. Policy recommendations

This current study has provided important outcomes that could be useful to researchers in the domain. In addition, it could involve to an improved orientation of schemes and programmes related to statistics knowledge. Therefore, certain recommendations could be made to government authorities, planners and policymakers, some of which already exist in programmes initiated to address statistics education in South Africa. However, most of these existing recommendations do not have a scientific, or empirical, basis, using specific information from South Africa, as certain information comes from old scientific research that reflect the past realities of the country. The socioeconomic and cultural context of the higher education in a given country has changed rapidly; therefore, the need for updated information does not suffer contradiction, even when they only confirm future results. Finally, this study has the merit of highlighting the particularities of UCT regarding the issue of statistics learning.

A benchmark as a guide for future research

There is no chance for good governance, without good knowledge of past and current situations, as well as a good vision and planning for the future. Policy-making is one of the key methods of safeguarding decent planning, which is the minimum requirement of a sustainable development. Unfortunately, very few statistics education researches focus on this area. The United Nations agencies, and other international agencies, are not enough to cover the demands of policy makers, planners and other statistics users, regarding the wide range of student issues, such as statistics learning. Therefore, this study was initiated to provide a benchmark. One of the objectives was to serve as guide for future research.

Consideration of a multi-disciplinary character of statistics learning

This recommendation aims more at collaboration between different development sectors’ programmes and projects. In fact, findings from this current research reveal that the risk of SELS beliefs has a gender component, as well as marital status, ethnic groups, emotion, behaviour, and social support components. Actors engaged in these domains should participate in decision-making on statistics learning programmes, as well as incorporate the issue as targets of their programmes and projects. In the researcher’s opinion, it is an effective and efficient solution to record a rapid decrease in the trend of SELS beliefs.

Knowledge transfer improvement in statistics monitors, supervisors and peers

Based on the findings of this research, we would recommend an improvement of knowledge transfer from the statistics monitors to students. Encouraging easy collaboration demands the availability of statistics monitors, and the appropriate communication between them and the students; however, it also involves the building of more connections of reference, as well as equipping peers in their capacity for interventions.

The findings further indicate the need to pay more attention to statistics monitors, and, in particular, the conditions of the transfer. Knowledge transfers in statistics are only efficient under the requirement of context, during the transfer of knowledge. Additionally, improving actions against failure in statistics learning is crucial,

when students are in critical situation, just after the judgment has been made, and lack of proper knowledge established. This recommendation will lead to satisfactory results, if emphasis is placed to increasing the number of meetings (as well as statistics monitors, who are well trained in statistics issues), and making offices available for consultations in most departments. The latter recommendations aim at bringing consultations closer to students, reducing distances, and improving conditions of good communication during knowledge transfer.

Consideration of specific population groups with important impact

This recommendation aims at the inclusion of, or at paying particular attention to some sub-populations, because of the important impact they have on statistics learning levels. The results of the analyses revealed that the female population should be encouraged, or granted more consideration, in programmes and projects related to statistics learning, as at UCT for instance, female students represented only 23.2% of the student body, compared to males. This situation may be due to lack of understanding regarding the importance of postgraduate studies, or cultural constraints, in terms of knowledge in mathematics, or female students encountered more opposition, when seeking better employment opportunities. However, this recommendation highlights female students as a target population for programmes and projects involving statistics learning.
Actions against failure in statistics learning should target females from their childhood. In addition, programmes about failure in statistics learning should be translated into ethnic languages, and awareness campaigns conducted in these ethnic groups' languages, to ensure that the message reaches entire population groups. Television and radio programmes should also be developed in these ethnic groups' languages.

Need for a specific national survey on statistics learning

This recommendation proposes a regular survey on statistics learning, covering the entire country with university representativeness. The lack of a national survey on statistics learning is a crucial problem, as censuses cannot incorporate enough questions to cover the education issue. A university survey, incorporating both distant and immediate risk factors of statistics learning, would provide better information, and allow better understanding of the problem, in all respects. Many actions are taken against failure in statistics learning, but there is no deep research, covering the entire country with complete data on statistics learning in South Africa. Such data is imperative to refine existent knowledge on the issue. A regular execution of the survey would be very useful for the monitoring and implementation of programmes and projects. The incorporation of statistics education into existent surveys, or censuses, could not replace the need for a full survey, well designed to capture and comprehend the issue. Further research studies need to be conducted into the improvement, or elaboration of a more precise methodology of statistics learning estimates, using full survey data.
The time consuming and restrictions of obtaining relevant data from other universities, the lack of more data from a broad viewpoint appears to be one of the limitations of this current study. Time data is required, to fit the time series model better, for the incorporation of both distant and immediate predictors of SELS beliefs in one model, and in the learning selection skills. In addition, only regional survey data provided information, allowing for only regional estimates of SELS beliefs. Finally, more qualitative data is required to compare the outcomes of the quantitative examination, with the opinions of experts, authorities, as well as the male and female students. This qualitative survey could have facilitated more clarification of the quantitative findings, as well as the experts' opinions about the inputs of the projection model.

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