

# An Experience of Statistical Methods on Several Tasks to Assess Analytical Skills Among Postgraduate Students

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## Abstract:

We explored students' experiences in postgraduate studies to investigate a set of empirical results from multiple situations, as well as develop possible theories that explain and predict how to select a relevant statistical test effectively. The participants were graduate students in the various departments at the university of the Western Cape (UWC). The findings demonstrate that the factors contributing to failure in the application of statistical procedures application include difficulty in applying statistics to real life problems, a lack of knowledge and non-familiarity with the items. The results also reveal that the confusion as well as conflicting concepts in statistics exacerbate the failure in statistical methods. This study provided important outcomes that could be useful to researchers in the domain. Further, it could result in an improved orientation of schemes and programmes related to statistics knowledge for UWC and universities across the country. The recommendations could be made to government authorities, planners and policymakers, some of whom already exist in programmes initiated to address statistics education in South Africa and Africa at large.

## Keywords:

Statistics Skills, Learning Statistics, Statistical Procedures, Conflicting Concepts, Postgraduate Studies

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## 1. Introduction

Although various studies on statistics education have been conducted worldwide [1,2,3], many aspects of statistics learning in developing countries, such as South Africa, have not been clarified, or explored [4]. This indicates that knowledge failure in statistics is a serious educational learning issue for students all over the world. The impact of the problem is more accentuated in developing countries, particularly in Africa [5]. In South Africa, as in many African countries, the problem of statistics learning is a major challenge for postgraduate students because of its complexity, the

lack of data and the poor quality of existing data [6]. Another concern for researchers and policy makers is the explanation for the failure of learning statistics, which involves a statistical model that is difficult to implement because of the weaknesses of existent data [7]. In addition to these difficulties, an important insufficiency of scientific work, related to this issue in South Africa, has been identified [8]. The consequences of knowledge failures in learning statistics have a dramatic effect on society, economics and innovation [9]. Little empirical research exists for similar initiatives in developing countries [3]. These facts, therefore, highlight the need for a tertiary approach to the problem of knowledge failure in statistics education. This situation has raised many questions, which motivated the initiation of this current research. The principal research question is, therefore, “How can statistics learning oriented policies at University of the Western Cape (UWC) in South Africa be efficiently improved?” Many subsidiary questions are also raised; “What attempts have been made, or actions already implemented, to reduce statistics learning failure?” and “What are the current and future consequences of statistical procedures application, if more attention is not paid to the problem?” The intention of this current research is to examine the level of knowledge and skills of postgraduate students, in applying appropriate statistical procedure in their studies.

Due to the progress made in statistical techniques over the years, involving presenting students with new statistics tasks might also be problematic [10]. The lack of statistical knowledge and practical experiences leads to anxiety among postgraduate students in their academic research [11]. Students still encounter difficulties in identifying the extent to which statistical procedure is appropriate to answer research questions, or to evaluate a variety of misconceptions, when applying real world problems [12]. There is a lack of an effective approach for students to follow, in order for them to gain a better understanding and interpretation of statistical procedures [13]. Therefore, the poor performance of students is differentially distributed among ethnic groups, and according to student status [2]. Urgent action is needed to address this specific problem for solutions, as the number of students with inadequate knowledge in statistics could increase dramatically. The development of a practical approach for post-graduate students to have a better understanding of applying statistical procedures effectively, adds to the significance of this current study.

To contribute to the body of knowledge on statistics learning issues, we have set as the main objective, the provision of statistical information on the causes of statistics procedures failure at university level, for a better orientation of related programmes. The aims are, specifically, to investigate a set of empirical results from multiple situations, as well as develop possible theories that explain and predict how postgraduate students choose a relevant statistical test.

## **2. Data and Methodology**

All students enrolled in postgraduate programmes were eligible to participate in this research project. The qualitative method combines a predetermined set of open-ended questions, as well as several statistical tasks, formulated ahead of time. The semi-structured interview starts out with more general questions, followed by prepared questions, and ends with questions that emerged during the interviews [14,15]. The selection method was purposive sampling, as the participants were available to provide easy access to special perspectives, as well as experiences that could facilitate a better understanding of the phenomenon under study. We met the prospective

participants individually, and requested their voluntary participation in the qualitative phase interviews. Furthermore, the researcher arranged individual meetings for the participants in safe, suitable, comfortable venues. Initially, the researcher made introductory small talk and revisited all the ethical considerations, before handing the participant the qualitative questionnaire of tasks (statistical test items) to complete. Initially, 7 students were purposively selected from different departments at UWC. Regrettably, two students withdrew from the study during the interview sessions as they found the tasks (statistical test items) beyond their ability and knowledge to accomplish.

We conducted one-to-one, semi-structured interviews with each participant prepared in advance. After the questionnaire of tasks was completed, we asked several analytical questions, such as “How did you decide?”; “Which information in the item notified or oriented you to that choice?”; “What will the test tell you?” The responses were transcribed and reported in categories or themes. Data was saturated when the researcher could no longer gather any new information, extract any new categories, or assign new inputs into new categories, from the data [16]. Ultimately, the data were captured in one file (qualitative data). Furthermore, we explore these participant experiences, as much as possible, focusing on their personal perspectives, experiences and understandings of the application of statistical procedures in their academic work. The effectiveness of semi-structured interviews depends on the communication skills of the interviewer [17]. Interpersonal skills help to establish humour, humility, relations and trust, expected to be present between the participants [18].

We arranged to meet them to meet during their break period, so as not to interrupt their academic programme. Participation in this phase of the research was voluntary, no incentives were offered, and there was no penalty for not participating or withdrawing during the interviews. In addition, for this qualitative phase, the same ethical considerations were adhered to, as per the quantitative phase. We deviated from the norm of interviews by preparing a questionnaire, with tasks and statistical test items, for the participants to complete/perform/select. The participants completed the questionnaire/tasks in 3 hours. We evaluated their responses, following their choice of statistical tests, applied in the different items of the questionnaire. Thereafter, the participants responded to detailed questions regarding the questionnaire/tasks, which lasted approximately 10 to 12 minutes. All records were transcribed and monitored for UWC. We ensured that all ethical requirements (informed consent, anonymity, privacy) were maintained for the qualitative phase. Information letters regarding the study were again relayed to the participants, via email. In addition, separate information letters, regarding the purpose of the study, were distributed to the lecturers, staff members of related departments, peer students and all the participants. Informed consent was obtained by disseminating individual consent forms to the participants, lecturers, staff members and peer students. All forms were administered in English, since it is the main language of instruction at universities in South Africa. We ensured that the participants were knowledgeable around the drive of the second phase of the research, the benefits to the participants, the extent of privacy, confidentiality and the freedom to withdraw from participation, at any phase and time [19].

Rigour was improved by paying considerable attention to the credibility and trustworthiness in the study [20]. After data collection, the descriptions of the perceptions and attitudes of the participants’ views, from all the interviews, were presented in verbatim transcriptions [21]. When the interviews were completed, the

researcher rechecked the interpretation and transcribed data with the participants, to validate their responses and identify themes. Clarifications needed to comprise some of succeeding issues: the nature of the study, the participants' potential role, the objective of the research, as well as how the results should be used [17].

### 3. Qualitative Findings

In this section, the researcher presents the results of the study, starting with a description of the participants. The qualitative data are transcribed and reported accordingly, while the results are discussed in section 4.

#### 3.1. Description of the Study Participants

Initially, the sample of participants was seven; however, two participants (black African male and female) withdrew during the interview session. Therefore, five participants were interviewed, comprising two females and three males, mostly aged older than 35 years old. Their racial statuses were four coloured and one white while their academic statuses were one master's student and four PhD students. Interestingly, they were also staff members, who described themselves as such, teaching statistics at undergraduate level at UWC.

#### 3.2. Participants' Responses

All the responses from five participants (Respondents 1-5) are presented below, extracted from the semi-structured interview data gathered:

**How did you decide to choose the test? Or on what basis did you choose the test that you had chosen?**

**Respondent 1:** *"I was looking at the task humm, so depending on the data and what outcomes were desired, I have been chosen the test."*

**Respondent 2:** *"Eheee, first of all, I tried to remember what I have learnt in statistics and then I looked for keywords that I will identify certain properties or characteristics of certain tests, then I looked at the data that was given, such as the size of the samples something like that. A process of thinking so going back to my undergraduate courses what I have learnt, the choice of a relevant statistical test should be made base on the sample size and the data."*

*"Okay, for some tasks there was no options, it was only that test could be used but in other tasks, I was confused. You have to look at the data, the set of variables, if it is only for example one set of data, if the variable is dependent or not independent, thing like that so those are the type of things you do have to look for instead of see how the data is displayed in the table that it gives you some directions in which way to go. And then you have to make a selection. Eheee especially with the correlation, there are different types of correlation you can do so you have to see based on actual information that's given to you, data set, is it repeated, thing like that totally give you better understanding of what test to select."*

**Respondent 3:** *"I read what information they give me right, and then, what I do I look at the test they gave me right. Now, there are certain information in the problem that they give me, like I would look at like say even they have given like a correlation and I will look at those tests where I know they make use of correlation Okay; and then, there were tests where the question wasn't*

*clear I mean the problem phrase wasn't so clear and then I would look at what type of analysis would I use humm especially with the factor analysis, discriminant analysis then I would look at that type of analysis I will implement."*

**Respondent 4:** *"Okay, on the high level for me when doing any research and relating to your research questions what is your objective is looking at the data, the high level question you have to ask yourself is what are the type of data I'm working on? Okay, at also choosing a statistics test really also humm goes handling with looking at the type of research done that similar to the research you have done and the type of test that was performed for that research it is not necessary one test that could work for the same research there is multiple tests and if there isn't a type of test that would rather serve to your objective you could consult you know with more senior statisticians to come up with a test which could satisfy your conditions."*

**Respondent 5:** *"I need to look to data or at least the questions, I could have feeling for what look familiar about it some have very familiar looking something could be a t-test or basic science test, that could be my major decision and then as I went too long, I would realize my power might be very low of my test, so if I had other option, I would consider that test but then I consider alternative test for high power you know to reject the null hypothesis."*

*"I suppose to the similar previous answer I think my decision was based on I will give maybe three reasons naturally just considering a type of question so giving or making assumption about the distribution taking a looking at any kind of possible weaknesses in the model or non-normality or the skewness of the distribution could be a possibility then I considered power in terms of rejecting for promises".*

**Which information in the item alerted you to that choice? What will the test tell you?**

**Respondent 1:** *"It was the combination of two things, the combination of the data itself; so I indeed looked at what data was available but and again using the outcomes and match the outcome to the type of the data that was available and I use those two criteria to evaluate."*

**Respondent 2:** *"Okay, as I said that again, you have to read everything and see what information is given to you, how the table is formulated or displayed how the information is displayed to you and then looking for words specific are like prediction, I saw a few times relationship between things, association, those type of words highlight to you, certain tests need to be performed; you have to look for those type of words and what information is given to you and then decide how to use it and what test will give you the right information."*

**Respondent 3:** *"First, I will look at those tests which I know right and I will look at the problem the item if the item has information which fits the test then I will link it if there is no link then I will need to look at the different test."*

**Respondent 4:** *"Looking at the type of variables, looking at the data, the difficult thing for me with this questionnaire for me I can ask questions ehee because some of the information yesterday but for me I would want to know more, so I found a little bit difficult actually answer these questions the way I*

*could because I'm the type of person that who want do something tiredly that would also took so long I don't like just quick, quick you know eheeyah."*

*"It depends on the objective again, so because handling hand with lot of objectives, depend on what you want to answer."*

**Respondent 5:** *"Sometimes the question would be rather leading, humm, that was generally I could on the occasion there be particular the same information I can missing data, items, there was a situation where, there was I can't remember entirely but I think there was the bit of the good feeling the data might be a quite skewed and that could give me a more non-parametric approach opposed to parametric approach."*

*"Generally I think there was hypothesis there was requiring and hopefully that would be able to give me confirmation of my feeling about the particular restriction of cause or rejecting of that hypothesis."*

### **Was it difficult to decide?**

**Respondent 1:** *"Yes, most of the tests that were available are not my specialty; they are not tests that I usually used so yes it was little bit difficult to decide."*

**Respondent 2:** *"Sometimes it was, sometimes I couldn't make the decision because I really didn't know and if it is a real life situation, then you have to do some research. Humm, that is all what we all have to do research to find out you know what is the best test or contact some of your colleagues if you don't know and discuss certain things like that because sometimes somebody else has better information and you have so. Sometimes I didn't know honestly, I didn't know what to do, so I just left that, I didn't know what to choose."*

**Respondent 3:** *"Yes, there were some tests which is difficult to decide ...humm because it's not a lot of information is given but a very last one where they give the observed, I wanted to apply a chi-square test but because the keyword in this correlation, you can't apply the chi-square to really a correlation, so I look at the other possibility of the correlation test and since, there I'm using the scenario that I'm not familiar with so that one was difficult."*

**Respondent 4:** *"Look at it, it's difficult in the sense especially you don't work with certain scenarios on the daily basis or it is not your area of expertise within the statistical field that's make it very very difficult because you know there is so many conflicting concepts in statistics you know certain statisticians believe, some people believe qualitative data can actually be quantitative because you should code, there is lot of debates around certain key concepts in statistics so it could be very confusing especially if it is not something you do daily; that's so I found because I'm newly back into this field again."*

**Respondent 5:** *"Yeah, ahahahaha, often, not always, often."*

### **Which information in the item made it difficult?**

**Respondent 1:** *"The outcomes again the outcomes."*

*"Depending of the outcomes that are needed I guess, the scenarios and the data also available."*

**Respondent 2:** “Humm, maybe that it wasn’t difficult to choose, just say maybe I didn’t know all of the statistical tests are there; I wasn’t familiar with all of the tests so I couldn’t decide what to use maybe to just little information to me to make a decision.”

**Respondent 3:** “Specifically those items where the information given is not very clear; you know, not a lot of information given to be able to fit a specific test to that item.”

**Respondent 4:** “Look if your scenario has a certain nature where, if multiple variables and there is especially when you can identify multiple tests that could be used for the same scenario that for me I could you know difficult to decide, for me then I would rather do let’s strobe wait and see and then logically loud it out.”

**Respondent 5:** “I think just the lack of exposure to certain kind of techniques, I think I haven’t for a long time use some techniques, some I have never been exposed to certain book of reading, and then also ... in fact the information was not completed in terms you didn’t see the data if you could plug it you could make it feel a little bit more comfortable or you could run a little bit of pre-test on it you feel little bit more comfortable.”

#### **Did alternative possibilities come to mind?**

**Respondent 1:** “No, because unfortunately I haven’t test any of these tests and it wasn’t in my area. Unfortunately, no I only use what was given to me to analyse which test to use.”

**Respondent 2:** “Humm, especially for the correlation questions, association, relationship between things, they have different options of pursue then you have to read further and look at how the information is given to you to decide which type of correlation you have to choose; so there are always it’s might be options and decide to go further little bit then see what is given to you it’s one sample, is it two samples, is it independent, not independent thing like that and then you can see which one to select basically.”

**Respondent 3:** “Yes, it was quite a few but because of lack of information in the scenario, you can’t really now say easy that one you know in real life you just apply the different alternative; but in this case, there wasn’t a plan where you can ask for extra information.”

**Respondent 4:** “Yeahh, of course.”

**Respondent 5:** “Absolutely.”

#### **Why were some tests rejected? / Did you think about some assumptions that you suppose to apply?**

**Respondent 1:** “I thought it didn’t apply to the data that was available. If I didn’t think that the test could be use according to the data available, I didn’t choose that test.”

**Respondent 2:** “Weeeehe, well if you don’t humm add here some of the rules of the specific tests so humm, it will give you the type of information as given to you will direct you in a certain way.”

**Respondent 3:** “Yes, they suppose like eehe none of the problem that I see where they will ask you the data is normal? There was one way they say invented data, now what does invented data means? Usually in this area invented data will be simulated data, you understand and you usually use simulated data to get estimates.”

**Respondent 4:** “If it doesn’t satisfy the criteria for the test, you know. You can do a t-test if there is no...whatever...”

**Respondent 5:** “I choose particular ones initially because of easy views and then I would often reject because I sound realise certain assumptions do not permit or allow and then there was not enough power.”

### **How confident are you about the decision you made?**

**Respondent 1:** “Hauf, I feel very confident. This, I am core confident.”

**Respondent 2:** “The one that I have answered I’m confident, some of them I wasn’t very sure but I didn’t know which other option to select. So some of them I took a guess especially with the comparing of the mean questions I took a guess there; humm yah I wasn’t exactly sure about that one.”

**Respondent 3:** “The easy ones, I’m very confident; ...humm the ending are the difficult ones because there were possible choices. Okay, I don’t use the parametric tests a lot which is applicable to normal test also, so I rather went for the easier test which is a normal assumptions and I stay away from the non-parametric test.”

**Respondent 4:** “Look, I didn’t spend too much time and I couldn’t ask a lot of questions on the scenarios and I’m feeling confident I think, really.”

**Respondent 5:** “I considered very confident.”

### **Please mention any items that you are not familiar with / May you mention some names?**

**Respondent 1:** “In terms of the tests? Post-hoc test for comparison of means, Factor analysis, Discriminant analysis, Semi-partial correlation, Kruskal and Wallis for One-way ANOVA for ranked data, Friedmann Two-way ANOVA for ranked data, Path analysis and Sandler’s A statistics.”

**Respondent 2:** “Okay, I will start at the bottom, the number 34 a Sandler’s A test; Path analysis; the Fischer exact probability test; Discriminant analysis, the Sign test, I’m not familiar with. Fisher z transformation, Factorial ANOVA, I’m not familiar with the Post-hoc test comparison of means that’s number 12 but I guess that one because just because of the words ...humm, what else’s. The Partial and Semi-partial correlation I’m not familiar with together that’s all it.”

**Respondent 3:** “Humm, the very last one Sandler’s A statistics, I have no idea what it is; ...humm, the Semi-partial correlation I haven’t heard about, ...humm, Partial correlation ...humm, the Fischer Z transformation I won’t say I’m not familiar with it but usually you do that for when you sit with the problem in your cells have small but I’m familiar with I want to know about but it is the way they say transformation usually you say Fischer exact test which is later on Fischer Z probability test; so... yah. Fischer exact Z transformation doesn’t make sense to me but, effect size, usually you say

*sample size so effect size right there usually you look like at in the inter axes but effect size I look at the problem then I couldn't see effect size what was the effect size I wasn't sure what the meaning of effect size; humm... Z statistics ... Yhhh, I won't say I'm not familiar but in other item that I look for I did choose one and use it but rather it should have been Z score than Z statistics or Z-test; it would be better than Z statistics let's put like confusing.'*

**Respondent 4:** *"Look there is lot of items I haven't come across like Path analysis or Sandler's A statistics, some of the tests are very widely used and common some tests are very specific for certain type of faculties or disciplines in the sense if you know what I mean, so I wouldn't necessarily come across these are even few that I haven't even seen before and even calculate before."*

*"Yeah, Path analysis, Friedman, Two way, Sandler's A statistics, Discriminant analysis."*

**Respondent 5:** *"I did myself unfair but I did study over items before I did the test. I went over all of them on the computer because I doubt the most of them I gonna pass. I would mention a few, number 9 the effect size I just want to know that refers to, I had really be exposed to all of those on the first page except the effect size, I little be confuse in, between 28 and 20 (Partial correlation and semi-partial correlation), I have been exposed to it but I don't remember the difference, I read that but I haven't convince of my understanding. Sandler's A statistics, I haven't seen it in my life the rest I'm familiar with it but I wasn't able to use them in my answers, I wasn't confident enough."*

#### **What are your feelings towards a choice of statistical test?**

**Resp. 4:** *"For some scenarios it's easy you can be confident because it's straight forward but the more complex objectives, the more conflicting your choices would be in terms of your decision; that's why I would say then, look at what has done try multiple different tests that could at least the test must satisfy the criteria to do the test you must make sure that you satisfy those criteria people you use it because otherwise you gonna come up with wrong statistics."*

#### **What factors hinder recovering the choice of statistical test?**

**Respondent 5:** *"Hoooo, I suppose it could be lack of confidence, in my understanding of a, the data and b, the test itself I think with common test the normal test with the data is it normal can I make the assumptions, with the less common test I would be better talking about assumptions that would making humm without understood the test completely correct."*

Constructivists view students as applying their own concepts, understandings, and principles to their academic work, which, in turn, affect how they appreciate and absorb new material. Rather than receiving material in class as it is delivered, students reorganise the new information to fit with their understanding. In this manner, they actively and individually build their own knowledge, rather than replicate knowledge transmitted or conveyed to them. In this regard, various themes and sub-themes arose from the comments of the participants, which were grouped into three main themes, namely, *the ability to choose a statistical test, perceived failures to choose the right test and non-familiar items.*

The main theme, ability to choose a statistical test, produced three sub-themes, namely, major concerns about a choice of a correct statistical test, practical knowledge needed to choose a statistical test and confidence about the decision made. Similarly, the main theme, perceived failures to choose the right test, produced two sub-themes, namely, causes of the difficulty in selecting a statistical test and reasons for the rejection of some tests. Regarding the main theme, non-familiar items, affected how the background of the respondents, the performance, the level of motivation, the level of knowledge and exposure to the statistics programmes were contributing factors to the degree of familiarity of students with various items. A detailed analysis of findings is presented in the next section.

#### **4. Evaluation of the Qualitative Findings at UWC**

The findings were subjected to thematic analysis. The choice of an appropriate statistical test depends on the types of the independent and dependent variables to analyse. Additionally, a participant must feel confident and have an interest to be involved in the study. The participants acknowledge that their choice of a statistical test would contribute to the assessment of their level of ability. This eventually would highlight, or reveal difficult conditions in which they made their responses. Despite having knowledge about the statistical test, some participants conceded that, they chose a test of convenience, as there was limited information available in the scenarios.

##### **4.1. Theme 1: Self-efficacy to Choose a Statistical Test**

Three sub-themes emerged from this theme: Major concerns about the choice of a correct statistics test, Practical knowledge needed to choose a test, and Confidence about the decision made.

##### **Major concerns about the choice of a correct statistics test**

The findings revealed that the participants experienced difficulty in using their ability, as their inspection of the data, as well as the expected outcomes, limited their flexibility to make a correct choice. This could be due to anxiety that relates to self-focused, negative and anxious reasoning during the learning process. [22] asserts that students with greatly STARS often hold comparatively negative SATS, under-report SELS beliefs, when associated to others. This experience was shared by participant 5, who said that he experienced difficulties in performing choice procedures:

*“My major concern was the non-understood the data well enough in terms of picking correct test with regards to assumptions particular concept like normality of the data as the aligned assumption generally I did like to go to non-distributed method to non-parametric method I found myself more comfortable with them humm, I feel computing power so I’m able to do with non-parametric method because for major concerns.” Participant 5*

Similarly, [23] argues that, in academic achievement, inferior levels of SELS beliefs are related to greater STARS, as well as greater disparities in task understanding. In this sense, participant 1 acknowledged that the understanding of the data, as well as the expected outcomes, helped him to make the relevant choice.

*“It was the combination of two things, the combination of the data itself; so I indeed looked at what data was available but and again using the outcomes*

*and match the outcome to the type of the data that was available and I use those two criteria to evaluate.”* **Participant 1**

All parametric tests adopt convinced principles about the information, also referred to as expectations. Violation of these conventions affects the decision of the investigation, and clarification of the outcomes may be biased [24]. Appropriately, in this current study, the findings indicated that respondent 4 insisted that the knowledge of assumptions, essential in statistical procedures, constitutes a great challenge that could coerce an individual to consult peer students.

*“Okay, on the high level for me when doing any research and relating to your research questions what is your objective is looking at the data, the high level questions you have to ask yourself is what type of data am I working on? Is it quantitative or qualitative then you have to look at the variable that you have if the variable spoolers some forms of descriptive, continuous distribution that leads you to the next question if say for example the variable is continuous there is a certain key question you have to ask you have to look at you don’t know how the data for that variable follow some certain normal distribution because the type of statistical tests you do limited to certain assumptions so if this normal normality or not that’s the key question that you have to look at.”*

**Participant 4**

The participants were concerned, generally, about their experiences in research and statistics, as well as frustrated by their efforts to understand the problem and use these experiences effectively. Their view was that they needed to learn how to use their experiences effectively. The findings of a study conducted by [25], corroborates this claim, by suggesting that, in general, the failure is due to undesirable practices in preceding statistics courses. This experience causes them to fear statistical concepts, and therefore, they assume they do not have sufficient mathematics experience to do well in statistics.

*“Okay, at also choosing a statistics test really ...humm also goes handling with looking at the type of research you have done that similar to the research you have done and the type of test that was performed for that research it is not necessary one test that could work for the same research there is multiple tests and if there isn’t a type of test that would rather serve to your objective you could consult you know with more senior statisticians to come up with a test which could satisfy your conditions.”* **Participant 4**

*“Eheee, first at all, I tried to remember what I have learnt in statistics and then I looked for keywords that I will identify certain properties or characteristics of certain tests, then I looked at the data that was given, see as the size of the samples something like that, a process of thinking so going back to my undergraduate courses what I have learnt looking at the sample sizes the data that was given and then trying to make a decision based on that.”*

**Participant 2**

The limited time allocated to complete all the items, also made it difficult to work alone, and thoroughly. However, by working alone, they were in control, and involved in every aspect of their choices.

*“I did myself unfair but I did study over items before I did the test. I went over all of them on the computer because I doubt the most of them I gonna pass.”*

**Participant 5**

*“Sometimes it was, sometimes I couldn’t make the decision because I really didn’t know and if it is a real life situation, then you have to do some research. Humm, that is all what we all have to do research to find out you know what is the best test or contact some of your colleagues if you don’t know and discuss certain things like that because sometimes somebody else has better information and you have so.” Participant 2*

### **Practical knowledge to choose a statistical test**

The participants experienced the test as a succession of problems that they had to solve. These problems included the inspection of data and keywords, identification of expected outcomes, interpretation of objectives, delineation of assumptions, application of previous experiences in statistics, checking different possibilities, and choosing the appropriate statistical test. Each item was experienced as stressful.

Concerning the inspection of data and outcomes, it was experienced as frustrating, demanding, and daunting. The participants became challenged and disillusioned. This finding concurs with the theoretical framework, as [26] postulate that students who experienced all these above features, are supposed to adapt some strategies during their learning process, such as learning from failures, which is an important facilitator of preparedness for both present and future tasks. Unfortunately, the failure of the students to address the difficulty to select the correct approaches tended to exacerbate this failure in statistics learning.

*“Looking at the type of variables, looking at the data, the difficult thing for me with this questionnaire for me I can ask questions ehee because some of the information yesterday but for me I would want to know more, so I found a little bit difficult actually answer these questions the way I could because I’m the type of person that who want do something tiredly that would also took so long.” Participant 4*

Regarding the interpretation of objectives and delineation of assumptions, the participants became irritated and pessimistic, especially when they presumed that there was no satisfactory outcome in their choice. This finding concurs with earlier findings, as [27] assert that when students are confronted with uncomfortable and unclear data, they do not think beyond the content, given that different possible interpretations are based on different assumptions. Students are misled because their experiences are based on wrong intuitions, errors and misconceptions to provide an appropriate answer, or choose a correct statistical method.

*“It depends on the objective again, so because handling hand with lot of objectives, depend on what you want to answer.” Participant 4*

*“Hoooo, I suppose it could be lack of confidence, in my understanding of a, the data and b, the test itself I think with common test the normal test with the data is it normal can I make the assumptions, with the less common test I would be better talking about assumptions that would making humm without understood the test completely correct.” Participant 5*

The participants understood that to apply previous experiences in statistics was not an easy task, and that it could be confusing. Although the assumption guidelines helped them immensely, the process does not necessarily advance in a specific and rigid sequence. They had to consider many tasks and decisions, simultaneously, to appreciate the differences. This finding concurs with a previous framework of [28], who indicate that postgraduate students from different cultural backgrounds have a

different understanding and interpretation of data. In the field of learning, students must critically approach new ideas, or concepts. Some of them interpreted these approaches as different from their previous academic environment.

*“I need to look data or at least the questions, I could have feeling for what look familiar about it some have very familiar looking something could be a t-test or basic science test, that could be my major decision and then as I went too long, I would realize my power might be very low of my test, so if I had other option, I would consider that test but then I consider alternative test for high power you know to reject the null hypothesis.”* **Participant 5**

*“I read what information they give me right, and then, what I do I look at the test they gave me right. Now, there are certain information in the problem that they give me, like I would look at like say even they have given like a correlation and I will look at those tests where I know they make use of correlation Okay.”* **Participant 3**

The students understood that making a choice of a test was not merely a rational process, but that external events may be of great value to enable the task. In all, they broadened their insight into, and their comprehension of, the nature of the event, as they experienced practical statistics, personally. Ultimately they assumed that they were well informed about the items, and better prepared to participate in the study. This finding concurs with those of [29], claiming that creative students are self-confident. Therefore, once they had solved a specific item, they were motivated, as well as confident about continuing, and more relaxed. Initially, they believed that choosing a statistical test was something they could merely pick and be done with: however, they later discovered that there was more to decide on than they thought. Consequently, they became worried and afraid of making mistakes.

*“Eheee, first at all, I tried to remember what I have learnt in statistics and then I looked for keywords that I will identify certain properties or characteristics of certain tests, then I looked at the data that was given, see as the size of the samples something like that, a process of thinking so going back to my undergraduate courses what I have learnt looking at the sample sizes the data that was given and then trying to make a decision based on that.”* **Participant 2**

*“I suppose to the similar previous answer I think my decision was based on I will give maybe three reasons naturally just considering a type of question so giving or making assumption about the distribution taking a looking at any kind of possible weaknesses in the model or non-normality or the skewness of the distribution could be a possibility then I considered power in terms of rejecting for promises.”* **Participant 5**

### **Confident about the decision made**

The participants initially underestimated the level of proficiency that this type of task required. The postgraduate students were very confident or positive because they perceived the task as relatively simple and straightforward. This finding concurs with that of [30], who argue that previously, learning approaches were more passive for students, which they had to implement in their lives by continuously repeating the process until they were confident enough.

*“I’m considered very confident.”* **Participant 5**

*“Hauf, I feel very confident. This, I am core confident.” Participant 1*

Students were under the impression that they knew what was expected of them, or they felt unsure, unable, and unwilling to become involved, doubting their ability to assume the responsibilities of a statistical test choice on their own. [31] emphasises that the student has to discover his/her own issues, aptitudes and solutions.

*“The easy ones, I’m very confident; ...humm the ending are the difficult ones because there were possible choices. Okay, I don’t use the parametric tests a lot which is applicable to normal test also, so I rather went for the easier test which is a normal assumptions and I stay away from the non-parametric test.”*

**Participant 3**

*“The ones that I have answered I’m confident, some of them I wasn’t very sure but I didn’t know which other option to select. So some of them I took a guess especially with the comparing of the mean questions I took a guess there; humm yah I wasn’t exactly sure about that one.” Participant 2*

However, the perception of the participants changed as the task progressed. When they took the initiative to make their own decisions, they experienced a personal revelation. They discovered hidden qualities and strengths in themselves, and they experienced the personal progress of their self-efficacy. Similarly, by considering the students’ ability, this current study confirmed the findings achieved by [32], who observed that students tend to interpret the new information, in terms of the knowledge they already hold, constructing their own meanings, by connecting the new idea to what they already believe.

*“Look, I didn’t spend too much time and I couldn’t ask a lot of questions on the scenarios and I’m feeling confident I think, really.” Participant 4*

Unfortunately, some of the participants encountered conflicting choices, contradictions and doubt in their decisions. They sensed that they needed support from peer students and senior statisticians, and became disillusioned when the expected help did not materialise, but very grateful when they did receive help. This finding is logical and is largely consistent with a significant body of literature, documenting the collaborative mentor-apprentice model that is applied for post-graduate instruction [33; 34]. Regardless, the supervisor still holds a prime position, acquired by training, maturity, and knowledge.

*“If there isn’t a type of test that would rather serve to your objective you could consult you know with more senior statisticians to come up with a test which could satisfy your conditions.” Participant 4*

*“Sandler’s A statistics, I haven’t seen it in my life; the rest I’m familiar with it but I wasn’t able to use them in my answers, I wasn’t confident enough.” Participant 5*

*“For some scenarios it’s easy you can be confident ... the more complex objectives, the more conflicting your choices would be in terms of your decision ... you will come up with non-sense statistics.” Participant 4*

Despite the fact that participant 5 tried to access the information via the network, before completing the task, he was still not confident enough about the selection.

*“I did myself unfair but I did study over items before I did the task. I went over all of them on the computer because I doubt the most of them I gonna pass.”*

**Participant 5**

#### **4.2. Theme 2: Perceived Failures to Choose the Right Test**

Little attention has been paid to the question on how to select the right statistical test in an academic environment. The process of the above task involved some difficulties that the participants experienced. In this current study, the researcher was concerned about the perceived failures to choose the correct statistics test. The participants realised that their choice of a statistical test could eventually reveal some difficulties that they had not expected. Two sub-themes were generated from this theme: Causes of difficulty to choose a statistics test, and Reasons for rejection of some tests.

##### **Causes of difficulty to choose a statistics test**

The learning process is valued by the quality of the knowledge, or skills acquired, or by the level of understanding of the basic concepts of statistics. The findings indicate that the participants were often anxious about choosing the relevant test. However, the results were quite interesting, from the researchers' perspective. The difficulties observed during the task practical, might be due to several factors, including, lack of information, lack of knowledge, lack of real world experience, non-familiarity with the items, mis-understanding of the items, confusion in interpretation of concepts, conflicting concepts in statistics and different areas of expertise. These results were not consistent with earlier findings. [30] determined that the learning process guides students to become aware of, and confront their misconceptions. These results make intuitive sense, in view of the fact that lack of information was reported by three participants.

*“Yes, there were some tests which is difficult to decide ...humm because it's not a lot of information is given but a very last one where they give the observed, I wanted to apply a chi-square test but because the keyword in this correlation, you can't apply the chi-square to really a correlation, so I look at the other possibility of the correlation test.”* **Participant 3**

*“In fact the information was not completed in terms you didn't see the data if you could plug it you could make it feel a little bit more comfortable or you could run a little bit of pre-test on it you feel little bit more comfortable.”*

**Participant 5**

*“I wasn't familiar with all of the tests so I couldn't decide what to use maybe to just little information to me to make a decision.”* **Participant 2**

The participants faced difficulties in choosing a correct test because of the lack of knowledge to complete some of the specific items. The students became discouraged, since in order to achieve their goals required tenacity, determination and commitment. The findings of a study conducted by [35] corroborates this claim that an achievement without motivation and construction of a work environment, would be impossible

*“Sometimes it was, sometimes I couldn't make the decision because I really didn't know and if it is a real life situation, then you have to do some research. Humm, that is all what we all have to do research to find out you know what is the best test or contact some of your colleagues if you don't know and discuss certain things like that because sometimes somebody else has better*

*information and you have so. Sometimes I didn't know honestly, I didn't know what to do, so I just left that, I didn't know what to choose." Participant 2*

*"Yes, most of the tests that were available are not my special; they are not tests that I usually used so yes it was little bit difficult to decide." Participant 1*

*"I think just the lack of exposure to certain kind of techniques; I think I haven't for a long time use some techniques, some I have never been exposed to certain book of reading." Participant 5*

Misunderstanding of and unfamiliarity with the items were also another source of difficulty which affected the ability of the participants to select a relevant test. [36] argue that the engagement of the student with the task requires previous knowledge and beliefs, his/her own clarification of the sense of the task, and its supplies. Participant 2 mentioned that she was not able to select the right test, due to some limitations, such as lack of awareness, knowledge and inexperience with such tests. The following evidence refers:

*"Humm, maybe that it wasn't difficult to choose, just say maybe I didn't know all of the statistical tests are there; I wasn't familiar with all of the tests so I couldn't decide what to use maybe to just little information to me to make a decision." Participant 2*

Additionally, scientists have been known to fool themselves with statistics, due to the lack of knowledge of theories, and the lack of standardisation of their tests [37]. In this sense, the master's student participant 3 claimed that, because the keyword in the item was correlation, he merely looked at other possibilities of correlation without checking the assumptions; evidently, he was confused about his procedure, and could not make a useful assessment.

*"Yes, there were some tests which is difficult to decide ...humm because it's not a lot of information is given but a very last one where they give the observed, I wanted to apply a chi-square test but because the keyword in this item was correlation, you can't apply the chi-square to really a correlation, so I look at the other possibility of the correlation test and since, there I'm using the scenario that I'm not familiar with so that one was difficult." Participant 3*

Furthermore, when dealing with concepts and interpretation accordingly, it is significant for the investigators to appreciate the basic concepts of the testing procedure, in order to make sound decisions about choices, results and to draw accurate conclusions.

*"There is so many conflicting concepts in statistics you know certain statisticians believe, some people believe qualitative data can actually be quantitative because you should code, there is lot of debates around certain key concepts in statistics so it could be very confusing especially if it is not something you do daily; that's so I found because I'm newly back into this field again." Participant 4*

*"Look if your scenario has a certain nature where, if multiple variables and there is especially when you can identify multiple tests that could be used for the same scenario that for me I could you know difficult to decide, for me then I would rather do let's strobe wait and see and then logically loud it out." Participant 4*

Data manipulation is a serious issue in statistical analyses. It is important to understand the data, concepts and fixing real problems, before choosing the right test to apply. However, participant 2 commented that effective participants, with amendable shortcomings, should be assisted and guided to complete the tasks.

*“Sometimes it was, sometimes I couldn’t make the decision because I really didn’t know and if it is a real life situation, then you have to do some research. Humm, that is all what we all have to do research to find out you know what is the best test or contact some of your colleagues if you don’t know and discuss certain things like that because sometimes somebody else has better information and you have so. Sometimes I didn’t know honestly what to do, so I just left that, I didn’t know what to choose.”* **Participant 2**

In addition, in Table 8.1 the area of expertise posed a challenge for the participants, who relied heavily on their prior experiences in statistics. Statistics has different fields of specialisation. Participants 1 and 4 reported that not having the necessary of background in a certain field may lead to the narrowing and distorting of the expected outcomes.

*“No, because unfortunately I haven’t test any of these tests and it wasn’t in my area. Unfortunately, no I only use what was given to me to analyse which test to use.”* **Participant 1**

*“Look at it, is difficult in the sense especially you don’t work with certain scenarios on the daily basis or it is not your area of expertise within the statistical field that’s make it very very difficult.”* **Participant 4**

### **Reasons for rejection of some tests**

Understanding the rejection of some statistical tests has proven to be very difficult, and many questions have remained unanswered for many decades. In this current project, various reasons for rejection emerged, including lack of knowledge, lack of information, misunderstanding of the concepts, confusion, assumptions not met, lack of evidence, criteria for the test not satisfied and not referring to peer students.

The lack of knowledge was shown by the participants not knowing what to do. Participants 1 and 2 became frustrated, as they were not able to establish an appropriate solution. [38] reveals that a student becomes more effective when s/he refines the feedback of her/his work, by interpreting the task, or adjusting internal goals, tactics and strategies.

*“Most of the tests that were available are not my special; they are not tests that I usually used so yes it was little bit difficult to decide.”* **Participant 1**

*“Sometimes I didn’t know honestly what to do, so I just left that, I didn’t know what to choose.”* **Participant 2**

*“Humm, maybe that it wasn’t difficult to choose, just say maybe I didn’t know all of the statistical tests are not there.”* **Participant 2**

Another concern raised by the participants for their failure to reject some of the tests was the lack of information, which created confusion and affected their achievement. In this regard, [39] claims that individual self-efficacy might be developed in a specific field, and while s/he has great self-assurance, s/he is more likely to try harder to achieve the task and obtain the desired outcomes.

*“but because of lack of information in the scenario, you can really now say easy that one you know in real life you just apply the different alternative; but in this case, there wasn't a plan where you can ask for extra information.”*

**Participant 3**

*“I wasn't familiar with all of the tests so I couldn't decide what to use maybe to just little information to me to make a decision.”* **Participant 2**

In addition, the misunderstanding of the concepts also increased the frustration and confusion of the participants in their approach to the tests. It was obvious that the degree of errors was likely to negatively affect their outcomes.

*“What does invented data means?”; “...rather it should have been Z score than Z statistics or Z-test; it would be better than Z statistics let's put like confusing.”* **Participant 3**

The complexity of many statistical ideas, assumptions and rules, constitute major challenges for students to ascertain the degree to which the choice provides the desired outcomes. These include, assumptions do not allow, do not satisfy criteria for the test, and insufficient evidence, which heavily influenced the rejection of some of the tests. [30] argue that when the students' lack of familiarity with the concepts and perhaps the way they interpret the data causes them to fail.

*“I would often reject because I should realise certain assumptions do not permit or allow and then there was not enough power.”* **Participant 5**

*“If it doesn't satisfy the criteria for the test, you know. You can do a t-test if there is no...whatever...”* **Participant 5**

The one believes that the data (independent variables) determine the effects observed on the dependent variables. The other attempts to understand a problem, but does not effect a change. The results are interesting when the participants are from diverse backgrounds. The difference between the best and the worst choice might be due to several factors, such as, a degree of familiarity with a specific test, the ability to select an adequate test, the ability to solve it, and the ability to apply prior experiences.

#### **4.3. Theme 3: Non-familiar Statistical Tests**

In this section, attention is focused on familiarity with statistical tests. The challenges arose because of the influence of the participants' multiple backgrounds on their learning processes, and the difficulty of unraveling the contributions of multiple approaches of teaching over time. These findings support earlier findings. [40] argues that self-efficacy beliefs influence students' aptitude for study. Their incentive and their achievement as individuals will frequently stimulate a desire to study and complete tasks which they trust will be fruitful. Changes in the strategies of learning might reflect differences that could be observed in the various characteristics of students, from one year to the next. [39] claims that the principle after the SELS beliefs theory is that achievement and incentive are, in part, solved by in what way active students trust they can be. Notably, examining the accuracy of the participants' responses in this current study, it was evident that, even among participants with the same level of knowledge, exposed to the same programme and reality (teaching statistics courses at undergraduate level), there was a variation in what they understood a statistical test bold, and its usefulness.

*“In terms of the tests? Post-hoc test for comparison of means, Factor analysis, Discriminant analysis, Semi-partial correlation, Kruskal and Wallis for One-way ANOVA for ranked data, Friedmann Two-way ANOVA for ranked data, Path analysis and Sandler’s A statistics”.* **Participant 1**

*“Ok, I will start at the bottom, the number 34 a Sandler’s A test; Path analysis; the Fischer exact probability test; Discriminant analysis, the Sign test, I’m not familiar with. Fisher z transformation, Factorial ANOVA, I’m not familiar with the Post-hoc test comparison of means that’s number 12 but I guess that one because just because of the words ...humm, what else’s. The Partial and Semi-partial correlation I’m not familiar with together that’s all it”.* **Participant 2**

*“Yeah, Path analysis, Friedman, Two way, Sandler’s A statistics, Discriminant analysis”.* **Participant 4**

*“I little be confuse in, between 28 and 20 (Partial correlation and semi-partial correlation), I have been exposed to it but I don’t remember the difference, I read that but I haven’t convince of my understanding. Sandler’s A statistics, I haven’t seen it in my life the rest I’m familiar with it but I wasn’t able to use them in my answers, I wasn’t confident enough”.* **Participant 5**

A discussion of the qualitative findings of the UWC study seems most significant. Although, moving away from the shared intellectual journey, with the self-efficacy beliefs to apply statistical procedures, attention should be paid to the complexity, and to some extent the unpredictability of both the institutional and regional borders.

Regarding UWC, this current study establishes that the respondents had trouble with applying their ability, as their inspection of the data and the expected outcomes limited their flexibility to make a right choice. As mentioned by [22], highly anxious students had negative self-concepts compared to others. In addition, the study revealed that the understanding of the data, and the expected outcomes enabled students to realise an appropriate choice. The participants were frustrated by their efforts to interpret real life problems; they expressed concern about using their experiences in research and statistics, effectively. [26] had similar findings, indicating challenged and disillusioned students should apply themselves to learn from their failures.

Regrettably, the failure of students to address the difficulties of selecting the correct approaches, tended to add to this failure in statistics learning. The students were irritated and pessimistic, because their experiences were based on false intuitions, mistakes and misconceptions. [28] assert that postgraduate students from diverse cultural circumstances have diverse understandings and interpretations of data. Students have to investigate new ideas and concepts critically. Some of the participants assumed that choosing a statistical test was a task they could simply do without consideration of the limiting factors; however, by progressing in the execution of the tasks, the students realised that there was more to it than they thought. Consequently, they became anxious and more specifically anxious about making mistakes. Similar findings were observed by [30], who claim that learning approaches are too passive for students, and should be implemented in their daily life, through continuous repetition until they became more confident. In this sense, [41] argue that each student needs to determine his/her own concerns, explanations and skills. By making their own decisions, the participants’ uncovered hidden strengths in their

abilities, for example, by constructing personal sense, by linking original ideas to what they previously knew.

Conflicting choices encouraged some participants to ask for help from peers and senior statisticians. Several reasons clarified the weaknesses of participants, namely, the lack of knowledge of theories, misunderstanding and confusion in the interpretation of the concepts, different areas of expertise, and unfamiliarity with the items. It was obvious that only pinpointing the keyword in an item was not sufficient to decide whether it was the right test to apply. Additional checking of the relevant assumptions, measurements of the variables, the data, sample size, and understanding the research question, was vital too for better decisions, and in order to draw accurate conclusions.

The area of expertise revealed a difference in the field of specialisation, which was an enormous challenge for the participants. [38] acknowledges that a student is more effective when he refines the feedback, by interpreting the task, as well as adjusting internal goals and strategies. Many statistical ideas, conventions and rules posed challenges for the students to determine the correct choice, which would provide the desired outcomes. These challenges included that the assumptions were not met, did not satisfy the criteria for the test, and too little evidence, which heavily influenced the rejection of some of the tests. [30] argue that the way students interpret data causes them to fail, in confusion.

One of the reasons may be the main interpretation of lecturers in higher education, namely that achievement or disappointment is solely the concern of the student. Students at UWC spend most of their time in one or two academic departments; therefore, it seems quite possible that the way students approach studying is influenced by the way the departments operate. Students are clearly aware that the departments differ in their attitude toward them, in the same way that they observe that some supervisors are more effective at conducting supervision. All these reasons comprise the external effect of course organisation on student learning.

Some of the participants were limited in their flexibility in choosing the right statistical test because of relatively negative self-concepts that underestimated the quality of their ability, while other students expressed concern about their use of statistical procedures, even when they were offered free assistance. In terms of the practical knowledge in selecting a statistical test, the participants experienced a succession of problems that they had to solve. Concerning confidence about the decision made, the participants initially underestimated the level of proficiency that the type of task required. The lack of information, lack of knowledge, difficulty with applying to real life problems, non-familiarity with the items, misunderstanding of the items, confusion in the interpretation of the concepts, conflicting concepts in statistics, different areas of expertise, the degree of familiarity with a specific test, inability to apply prior experiences, too little evidence, criteria for the test has not been satisfied (assumptions), as well as not referring to peer students and statistics monitors, might be the reasons for the difficulty observed during the practical task. The challenges arose because of the influence of the multiple backgrounds of the participants, as well as the difficulty of separating the contributions of these multiple approaches of teaching over time, from the students' learning process.

Many of the findings of this current research have immediate relevance to supervisors who wish to improve their supervision, as well as for students who want to improve their method of studying. In addition, there are important implications for

the enhancement of the efficiency of learning in the costly business of higher education. Currently, efficacious and weak students remain unchanged by the supervision and courses they encounter. Individual differences and the university environment interact subtly and continuously; therefore, a proper understanding of student learning needs to address both components. The focus is on the student's journey, as well as how it is influenced, for better or worse, by the environment in which it takes place.

## **5. Conclusions: How do the Students Choose the Appropriate Statistical Test?**

The above-mentioned objective was to describe the way in which the task of choosing a statistical test was carried out on UWC Bellville campus. The participants were well informed about the interview. Three sub-themes emerged from this research question, namely, self-efficacy in choosing a statistical test, perceived failure to choose the right test, and unfamiliarity with statistical tests. Regarding self-efficacy in choosing a statistical test sub-theme, the most common responses highlighted some of the key features of the participants' manner of choosing, such as careful inspection of the data, understanding the problem, experiences in research and in statistics, as well as their awareness they must check for different possibilities. For those who perceived they would fail to choose the right test sub-theme, some reasons were a lack of knowledge, confusion in interpretation, expertise in areas expertise different from that in which the tests originated, and the conflicting concepts the participants had acquired in statistics. The unfamiliarity with statistical tests sub-theme indicated a failure in the learning process because of the multiple backgrounds of the respondents, difficulty in separating the contributions of multiple approaches to teaching over time from the participants' learning process.

Some of the participants were limited in their flexibility in selecting the right statistical test, because of relatively negative self-concepts that underestimated the quality of their ability, while other participants expressed concern about their use of statistical procedures, even when they were offered free assistance. In terms of the practical knowledge to choose a statistical test, the participants experienced a succession of problems that they had to solve. Concerning confidence about the decision made, the participants initially underestimated the level of proficiency that the type of task required. The lack of information, lack of knowledge, difficulty in applying the test to real life problems, non-familiarity with the items, misunderstanding of the items, confusion in the interpretation of the concepts, conflicting concepts in statistics, different areas of expertise, the degree of familiarity with a specific test, inability to apply prior experiences, a lack of evidence, criteria for the test had not been satisfied (assumptions), as well as not referring to peer students and statistics monitors, might be the reasons for the difficulty observed during the practical task. The challenges arose because of the influence of the multiple backgrounds of the participants, as well as the difficulty of separating the contributions of these multiple approaches of teaching over time, from the participants' learning process.

## **6. Policy Recommendations**

This current study has provided important outcomes that could be useful to researchers in the domain. In addition, it could contribute 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.

### ***6.1. Knowledge Transfer Improvement in Statistics Monitors, Supervisors and Peers***

The findings of this current research 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, instigating interventions against failure in statistics learning is crucial, when students are in a 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 on 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.

### ***6.2. Particular Attention to Young Postgraduate Students***

This recommendation responds to the high risk of failure in statistics learning by young post-graduate students. The decline in the performance in statistics of post-graduate students in the 20-25 and 26-30 age groups may be the consequence of learning method failures. Although some may consider learning selection skills unimportant in a statistics course as they may think they can just choose the appropriate test from a book, they do not take into account that there are no guidelines for selecting a suitable statistical test. A special programme is required to train, or assist young postgraduate students in learning about selection skills and statistics learning risk factors. Young graduate students should be involved in this programme, and subject to available funds, the programme could be extended to all postgraduate students. Such a programme could even involve all the students at the University.

### ***6.3. Consideration of a University Approach to Knowledge Failure in Statistics Learning***

This recommendation supports the consideration of the university specificities in the design of programmes and projects related to failure in statistics learning. The university approach suggests that each university should have its particular answer to the statistics learning problem, and a committee set up for its monitoring and implementation. This recommendation aims to bridge the huge gap between universities, in terms of levels and risks of statistics failure. Budget allowances should also follow a business and ethically based dispensation of funds according to the urgent and crucial needs of some universities. Preference, or deep consideration, should be accorded to universities that appear to be most at risk of failure in the country. This study recommends an in-depth investigation into the wide gap at universities in South Africa, in terms of failure in statistics learning, and calls for

urgent and dynamic action in order to reduce the level of knowledge failure in statistics.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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## References

- [1] Clark, I. Formative assessment: Assessment is for self-regulated learning. *Educational Psychology Review*, 2012, 24(2), 205-249.
- [2] Froehlich, L. Ability-related stereotypes predict group differences in students' performance and student teachers' causal attributions for academic underperformance. Unpublished Doctoral dissertation in Psychology, University of Konstanz: Baden-Württemberg, Germany, 2015. Available online: [https://kops.uni-konstanz.de › Froehlich\\_0-293348](https://kops.uni-konstanz.de › Froehlich_0-293348) (accessed on 10 March 2021).
- [3] Kamleu, G.; Holtman, L.; Yan, B. Ordinal Regression Analysis of Post-Graduate Students' Attitudes Towards the Application of Statistical Procedures in a South African University. *Education Journal*, 2020, 3(2), 53-71.
- [4] Bray, M.; Thomas, R.M. Levels of comparison in educational studies: Different insights from different literatures and the value of multilevel analyses. *Harvard Educational Review*, 1995, 65(3), 472-491.
- [5] Kamleu, G.; Yan, B.; Holtman, L. Ordinal Regression Analysis of Students' Ability to Learn Statistics: A New Look at Operations Improvement for Statistics Education. *International Journal of Innovative Science, Engineering & Technology*, 2021, 8(2).
- [6] Janssen, M.; Charalabidis, Y.; Zuiderwijk, A. Benefits, Adoption Barriers and Myths of Open Data and Open Government. *Journal Information Systems Management*, 2012, 29(4), 258-268.
- [7] Majone, G. Evidence, argument, and persuasion in the policy process. Yale University Press: New Haven, CT, USA. 1989.
- [8] Banks, J.A. Multicultural Education: Historical Development, Dimensions, and Practice. In J. A. Banks, & C. A. M. Banks (Eds.), *Handbook of Research on Multicultural Education* (2 ed., pp. 3-29). Jossey-Bass: San Francisco, CA, USA, 2004. ISBN: 0787959154 9780787959159.
- [9] Argote, L. Organizational learning: Creating, Retaining and Transferring Knowledge. Springer: New York, NY, 2012; DOI: 10.1007/978-1-4614-5251-5.
- [10] Artino, A.R. Academic self-efficacy: From educational theory to instructional practice. *Perspectives on Medical Education*, 2012, 1(2), 76-85.

- [11]Perepiczka, M.; Chandler, N.; Becerra, M. Relationship between graduate students' statistics self-efficacy, statistics anxiety, attitude toward statistics, and social support. *Professional Counselor*, 2011, 1(2), 99-108.
- [12]Zhang, Y.; Shang, L.; Wang, R.; Zhao, Q.; Li, C.; Xu, Y.; Su, H. Attitudes toward statistics in medical postgraduates: Measuring, evaluating and monitoring. *BMC Medical Education*, 2012, 12, 117-6920-12-117.
- [13]Clark, I. Formative assessment: Assessment is for self-regulated learning. *Educational Psychology Review*, 2012, 24(2), 205-249.
- [14]Rowley, J. Conducting research interviews. *Management Research Review*, 2012, 35(3/4), 260-271.
- [15]Creswell, J.W. Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). Sage: Thousand Oaks, CA, USA, 2014, pp. 1-273; ISSN 1916-4742. DOI: 10.5539/elt.v12n5p40.
- [16]Babbie, E. The practice of social research. 13<sup>th</sup> ed. Wadsworth: Belmont, CA, USA, 2012; pp. 1-584. ISBN 13: 9781133049791.
- [17]Onwuegbuzie, A.J.; Leech, N.L.; Slate, J.R.; Stark, M.; Sharma, B.; Frels, R.; Harris, K.; Combs, J.P. An exemplar for teaching and learning qualitative research. *The Qualitative Report*, 2012, 17(1), 16-77.
- [18]Cohen, L.; Manion, L; Morrison, K. Research Methods in Education. 8th ed. Taylor & Francis Group: London, UK, USA, 2017; pp. 1- 944, ISBN 9781138209862. DOI: 10.4324/9781315456539.
- [19]Silverman, D. Doing Qualitative Research A Practical Handbook. 4th revised ed., SAGE Publications Inc: Thousand Oaks, California, USA, 2016; ISBN 13: 9781473916579.
- [20]Robson, C. Real world research: A resource for users of social research methods in applied settings (3rd ed.). Blackwell: Oxford, UK, 2011; ISBN: 978-1-405-18241-6.
- [21]Yilmaz, K. Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education*, 2013, 48(2), 311-325.
- [22]Geary, D.C.; Boykin, A.W.; Embretson, S.; Reyna, V.; Siegler, R.; Berch, D.B; Graban, J. Report of the task group on learning processes. In National Mathematics Advisory Panel, Reports of the task groups and subcommittees. Department of Education: Washington, DC, USA, 2008; pp. 4-2 to 4-10. Available online: <http://www2.ed.gov/about/bdscomm/list/mathpanel/report/learning-processes>. (accessed on 10 August 2018).
- [23]Hembree, R. Correlates, causes, and treatment of test anxiety. *Review of Educational Research*, 1988, 58(1), 47-77.
- [24]Osborne, J.W. Improving your data transformations: Applying the box-cox transformation. *Practical Assessment, Research & Evaluation*, 2010, 15(12), 1-9.
- [25]Onwuegbuzie, A.J. Writing a research proposal: The role of library anxiety, statistics anxiety, and composition anxiety. *Library and Information Science Research*, 1997, 19, 5-33.

- [26] Cannon, M.D.; Edmondson, A.C. Failing to learn and learning to fail (intelligently): How great organizations put failure to work to innovate and improve. *Long Range Planning*, 2005, 38(3), 299-319.
- [27] Ben-Zvi, D.; Garfield, J. B. Statistical Literacy, Reasoning and Thinking: Goals, Definitions, and Challenges. In D. Ben-Zvi, & J. B. Garfield (Eds.), *The Challenge of Developing Statistical Literacy, Reasoning, and Thinking*, 1st ed., Kluwer Academic Publishing: Springer, Netherlands, 2004; pp. 3-16, eBook ISBN: 978-1-4020-2278-4, DOI: 10.1007/1-4020-2278-6. Available online: <https://experts.umn.edu/en/publications/statistical-literacy-reasoning-and-thinking-goals-definitions-and> (accessed on 10 March 2018).
- [28] Schunk, D.H.; Pajares, F. Self-efficacy beliefs. In: P. Penelope; B. Eva; M. Barry (eds.), *International encyclopedia of education*. Elsevier: Oxford, UK, 2010; pp. 668–672.
- [29] Stein, M.I. *Stimulating creativity: Individual procedures*. 1st ed. Academic Press: Hershey PA, USA, 2014; pp. 1- 368, ISBN-13: 978-1483246901.
- [30] Garfield, J.; DelMas, R.C.; Chance, B. Using Students' Informal Notions of Variability to Develop an Understanding of Formal Measures of Variability. In: M. Lovett and P. Shah [eds.], *Thinking with Data*. Lawrence Erlbaum Associates: Mahwah, NJ, 2007; pp. 117-148.
- [31] Boud, D. *Enhancing learning through self-assessment*. Routledge Falmer: London, UK, 2013; pp. 1-256, eBook ISBN: 9781315041520. DOI: 10.4324/9781315041520.
- [32] Ally, M. Foundations of educational theory for online learning. In *The Theory and Practice of Online Learning*, 2nd ed. Athabasca, Alberta: Athabasca University Press, 2008, 2, 15-44. Available online: <http://www.aupress.ca/index.phd/books/120146> (accessed on 10 August 2018).
- [33] Anderson, E.S.; Wojcik, J.R.; Winett, R.A.; Williams, D.M. Social-cognitive determinants of physical activity: The influence of social support, self-efficacy, outcome expectations, and self-regulation among participants in a church-based health promotion study. *Health Psychology*, 2006, 25(4), 510-520.
- [34] Reed, Y. Mediating knowledge and constituting Subjectivities in Distance Education Materials for Language Teachers in South Africa. Unpublished PhD thesis. Faculty of Humanities, University of the Witwatersrand, South Africa. 2010; pp. 1-346.
- [35] Brophy, J.E. *Motivating students to learn*. 3rd ed., Routledge: New York, NY, USA, 2013, ISBN-13: 978-0415800709.
- [36] Nicol, D.J.; Macfarlane-Dick, D. Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 2006, 31(2), 199-218.
- [37] Teddlie, C.; Tashakkori, A. Mixed methods research: Contemporary issues in an emerging field. In: N.K. Denzin & Y.S. Lincoln [eds.]. *The Sage handbook of qualitative research* [4<sup>th</sup> ed.]. Sage Publications Ltd: Thousand Oaks, CA, 2012; 56(6), ISBN: 978-1-4833-4980-0. DOI: 10.1177/0002764211433795.
- [38] Bandura, A. On the functional properties of perceived self-efficacy revisited. *Journal of Management*, 2012, 38(1), 9-44.

- [39] Redmond, B.F. Self-Efficacy Theory: Do I think that I can succeed in my work? Work Attitudes and Motivation. Pennsylvania State University, World Campus, 2010. Available online: <https://cms.psu.edu> ((accessed on 15 August 2018)).
- [40] Lunenburg, F.C. Self-efficacy in the workplace: Implications for motivation and performance. *International Journal of Management, Business, and Administration*, 2011, 14(1), 1-6.
- [41] Boud, D.; Keogh, R.; Walker, D. Reflection: Turning experience into learning. 1st ed., Routledge Falmer: New York, NY, USA, 2013; pp. 1-172, ISBN 9781138984820. DOI: 10.4324/9781315059051.



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