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Original Article

Factors that Promote Successful Supervision of Doctoral Statistics Students in Kenya: A Literature Review

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ABSTRACT

This study delves into the reasons behind Kenya's insufficient production of PhD graduates in statistics to meet its demands and what needs to be done to promote higher completion rates. The paper reviewed current literature guided by four specific inquiries: (i) What factors associated with students influence the successful completion of PhD studies in Statistics? (ii) How do issues pertaining to statistics lecturers impact the supervision and mentoring of PhD students? (iii) How does the university environment affect the performance of PhD students in statistics? (iv) What global and Kenyan models have been employed for the training and supervision of PhD students? The study's conceptual framework encompasses four fundamental factors related to these research questions. Two factors fall under the category of human characteristics, while the remaining two relate to course delivery. These domains collectively shape the quality of supervision offered to statistics PhD students. The findings reveal that students often lack a strong foundation in the theory of research methods and statistics. Furthermore, financial constraints frequently hinder their progress and graduation. Additionally, there is a shortage of qualified statistics lecturers, and those available often lack robust supervision skills. Universities in Kenya face resource shortages, including insufficient access to computers and software, which impacts the research environment. The current Humboldtian model of supervision practised in Kenya is criticized, partly due to its limited flexibility to respond to rapidly changing curricula. In conclusion, the evidence available advocates a holistic approach to enhance the capacity-building process and mentoring of doctoral students in statistics in Kenyan universities.

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INTRODUCTION

The field of statistics encompasses data compilation, cleaning, and analysis, aiming to utilize the resulting information for decision-making. Probability theory and statistical inference form the foundation of statistical analysis, both rooted in mathematics (Larsen, 2017). Statistics finds application in various fields such as economics, medicine, agriculture, and engineering. Students of statistics, whether in theoretical or applied domains, often utilize data from other disciplines to develop theories and methodologies or test existing ones.

The formal study of modern statistics likely originated at University College London, where Karl Pearson established the world's first university statistics department (University College London, 2020). Other universities globally, such as Johns Hopkins University (Rohde et al., 2013), Indian Statistical Institute (Ghosh, 1994), and Columbia University (Zheng & Yi, 2012), have since established departments focusing on theoretical and applied statistics at both undergraduate and postgraduate levels.

In Africa, the first statistics department was founded at the University of Pretoria in 1938 (University of Pretoria, 2024), with Stellenbosch University establishing its department in 1946 (University of Stellenbosch, 2013). South African universities boast some of the oldest and most well-established statistics departments on the African continent. In Kenya, university-level statistics courses were started at the University of Nairobi within the Department of Mathematics. To meet the growing demand for postgraduate studies in statistics, several Kenyan universities, including Maseno University, Jomo Kenyatta University of Agriculture and Technology, and Taita Taveta University have also established their master's and PhD programs, either within mathematics departments or as standalone departments in statistics.

The rising demand for PhDs in statistics is associated with the increasing need for skills to handle big data in the expanding knowledge economy (Mouton & Frick, 2018). Surveys in the United States show a general increase in the number of awarded PhDs in statistics, indicating a high demand for qualified statisticians (Vélez et al., 2013; Pierson, 2018). The number of PhDs awarded in various fields of statistics also rose by 113% from 230 to 811 between the years 2001 and 2022. Further, the percentage of PhDs in statistics and biostatistics in the United States that were unemployed between 2008 and 2015 ranged from 1.8% to 4.2%. These figures indicate a high demand for highly qualified statisticians. While these data primarily reflect the American market, anecdotal evidence suggests a more acute scarcity of statistics on PhDs in Kenya. Taita Taveta University and Pwani University in Kenya, for example, have only two and four statisticians with PhD qualifications respectively, all trained outside Kenya. Matas (2012) also suggests that once doctoral students in statistics are successfully supervised and graduate, they may not go back to their countries of origin due to higher remuneration elsewhere.

Successful doctoral student supervision in this paper is described as the process of guiding a doctoral student to graduate in a timely and collegial manner while fulfilling all the requirements of the university. Successful supervision of statistics PhDs, therefore, demands a convergence of favourable factors such as student attributes, supportive lecturer factors, institutional resources, appropriate training models, and a robust curriculum. European universities have identified similar issues in the Salzburg Principles (European Commission, 2011) to enhance the quality of PhD student recruitment and supervision. Kenyan universities, constrained by limited resources, face difficulties in optimizing these factors, resulting in a low production of doctoral statistics graduates (Odhiambo & Onyango, 2018). This paper seeks to address the overarching question

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of why Kenya struggles to produce sufficient PhD graduates in statistics and explores specific factors related to students, lecturers, and the university environment. The literature review was guided by four specific questions: (i) What factors associated with students influence the successful completion of PhD studies in Statistics? (ii) How do issues pertaining to statistics lecturers impact the supervision and mentoring of PhD students? (iii) How does the university environment affect the performance of PhD students in statistics? (iv) What global and Kenyan models have been employed for the training and supervision of PhD students? The following sections of this paper include the methodology, findings, discussion, conclusions, and recommendations.

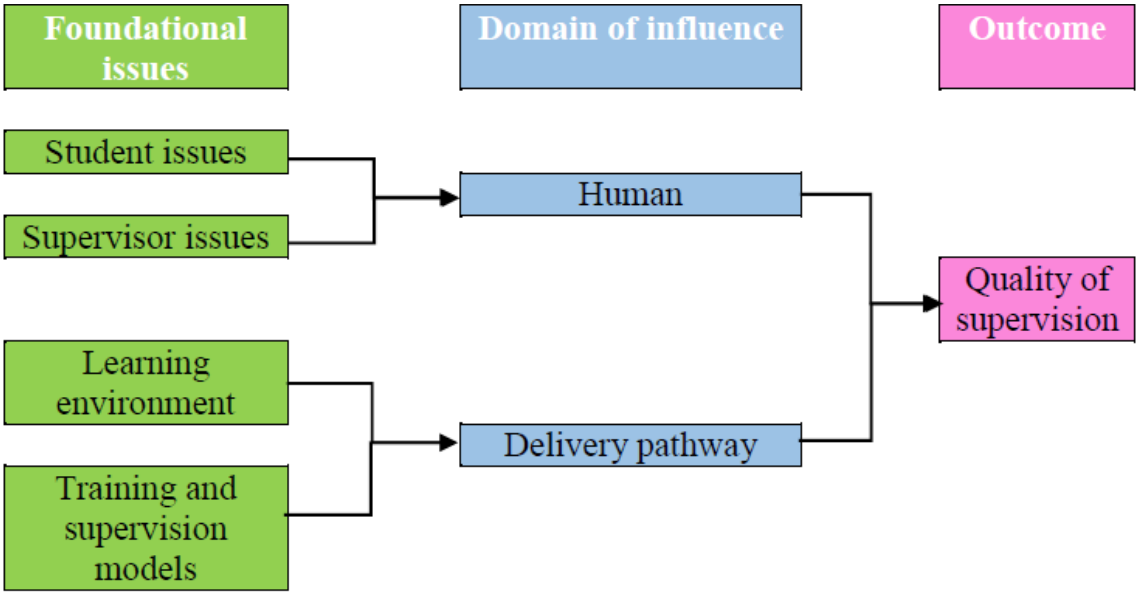
MATERIALS AND METHODS

The methodology adopted for this study encompassed a comprehensive desk review, involving an examination of existing literature pertaining to supervision. The specific focus is on the supervision of doctoral students in statistics.

Conceptual Framework

To structure the investigation, a conceptual framework (Fig 1) was developed from the research questions. As illustrated in the figure below, this framework outlines the interplay of the four specific questions as foundational issues influencing the supervision of doctoral candidates. Two of these issues or factors are situated within the realm of human characteristics, while the remaining two reside in the domain of course delivery. The dynamics between these two domains collectively shape the overall quality of supervision encountered by PhD statistics students.

Figure 1: Conceptual Framework for Supervision of Doctoral Statistics Students



Source: Author

RESULTS

This review included forty-two publications that discussed the four foundational issues in the conceptual framework. Table 1 summarizes the key issues from each of the publications. The results in the various publications were evaluated in relation to the conceptual framework. The evaluation is presented in the discussion section of this study.

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Table 1. Thematic Synthesis of Reviewed Literature

Theme	Publication in Order of Appearance	Type of Publication	Synthesis
Context of study	University College London, 2020	Webpage	Developmental history of the statistics department
	Rohde et al., 2013	Article	Developmental history of the statistics department
	Ghosh, 1994	Article	Statistics history in India
	Zheng & Yi, 2012	Book chapter	Developmental history of the statistics department
	University of Pretoria, 2024	Webpage	Developmental history of the statistics department
	University of Stellenbosch, 2013	Webpage	Developmental history of the statistics department
	Mouton & Frick, 2018	Article	Demand for PhDs
	Vélez et al., 2013	Article	PhD graduation rate in the USA
	Pierson, 2018	Article	PhD graduation rate in the USA
	Matas, 2012	Article	Marketability of PhDs
	European Commission, 2011	Report	Salzburg Principles
Issues affecting student performance	Odhiambo & Onyango, 2018	Proceedings	• Training resource constraints • Inadequate number of lecturers • Delayed graduations • Impact of scholarships on graduation
	Bulmer et al., 2007	Proceedings	Threshold concepts in PhD statistics
	MacDougall, 2010	Proceedings	Threshold concepts in PhD statistics
	Wills, 2017	Article	Threshold concepts in PhD statistics
	Meyer & Land, 2005	Article	Threshold concepts in PhD statistics
	Beitelmal et al., 2022	Article	Threshold concepts in PhD statistics
	Linde, 2016		Probability theory as a core threshold concept
	Keefer, 2015	Article	Liminality in doctoral students
	Olaniyi, 2020	Article	Liminality in doctoral students
	Botha & Mouton, 2018	Training Manual	Oral defense challenges
	Mouton, 2001	Book	Application of theory to research
	Kiley, 2015	Article	Application of theory to research
	Stellenbosch University, 2018	Online discussion	Funding for PhD students
Issues affecting supervisor performance	Egan et al., 2009	Article	Lecturer work overload
	Mukhwana et al., 2016	Proceedings	Lecturer work overload
	Maseno University, 2018	Proceedings	Supervision skills
	de Lange et al., 2011	Article	Supervision approach
	Munene, 2024	Online article	Mentoring
	Gatfield, 2005	Article	Mentoring
	Lee, 2008	Article	Mentoring
	Hassad, 2010	Proceedings	Mentoring
	Maseno University, 2018	Proceedings	Supervision and mentoring skills
	AMREF, 2024	Webpage	Supervision and mentoring skills

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Influence of university environment on student and supervisor performance	Obwogi, 2011	Dissertation	Institutional resource scarcity
	Wanzala, 2018a	Webpage	Government funding
	Jiang et al., 2019	Article	Online PhD programmes
	Botha, 2018	Training module	Training models
	Kiley, 2017	Proceedings	Training models
	Olaniyi, 2020		Threshold concepts in PhD statistics
	Wanzala, 2018b	Webpage	Coursework for PhDs

DISCUSSION

Student Issues

To analyze and interpret research data effectively, students pursuing a PhD in statistics must possess a robust theoretical foundation in mathematics. Kenyan universities typically admit students with a significant background in mathematics or related quantitative courses at the undergraduate and master's levels into their PhD statistics programs. This strategy aims to ensure a strong theoretical foundation for success at the doctoral level. However, the rapid expansion of undergraduate classes in Kenyan universities and numbers without a proportional increase in the number of lecturers (Odhiambo & Onyango, 2018) has led to the output of lower-quality graduates. This situation leaves students insufficiently prepared for PhD studies because there is no provision for remedial coursework in the statistics doctorate curriculum. Inadequately prepared students may face difficulties in their studies as they struggle to comprehend crucial concepts at the threshold of doctoral candidature (Bulmer et al., 2007; MacDougall, 2010; Wills, 2017) and thereafter produce lower-quality theses. Threshold concepts are described as the core knowledge necessary for comprehension and practice within a study field (Meyer & Land, 2005; Beitelmal et al., 2022). In postgraduate statistics courses, these concepts include probability theory, distributions, estimators, hypothesis testing, expectations and random variables (Linde, 2016).

The global challenge of not grasping threshold concepts, a handicap referred to as liminality, particularly affects students lacking a firm theoretical foundation (Keefer, 2015; Olaniyi, 2020). Liminality further leads to inadequate knowledge of what an oral thesis defence entails. As a result, ill-prepared students often encounter difficulties during the oral defence stage of their theses further hindering their efforts to succeed (Botha & Mouton, 2018). Students also need to be proficient in the theory and practice of research methodology to overcome liminality. Inadequate preparation in research methodology negatively affects how students translate real-world problems into scientific problems and also how to apply theory to research problems (Mouton, 2001; Kiley, 2015). In the Kenyan context, where most PhDs are earned through research and thesis, students with limited ability to formulate a conceptual framework or research hypotheses due to liminality may struggle. A solid mathematical background does not guarantee good conceptualization skills either if not supported by a research methods course. Although a research methods course at the master's level aims to equip students with the necessary conceptualization skills, it doesn't always happen. Learning research methods is often challenging for students because of its demand for logical reasoning skills, making it one of the more difficult courses to comprehend. However, unlike many other fields of study, empirical research is not obligatory for a PhD in statistics. Research activities often revolve around the analysis and interpretation of pre-existing data, either raw data from experiments or surveys conducted by other researchers. Additionally, students simulate data through computer programming. However, a novice student lacking sufficient computing skills may encounter hurdles in generating appropriate data through simulations, potentially causing unnecessary delays towards graduation (Odhiambo & Onyango, 2018).

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PhD students in Kenya face the additional challenge of self-financing their studies, a common issue for many African students. Limited finances often delay students on their journey to graduation (Stellenbosch University, 2018). Many of these students are employed full-time, making their PhD studies part-time. This poses challenges, as part-time students must allocate resources from their full-time jobs to fund and manage a part-time endeavour that has delayed benefits. This challenge is particularly pronounced for statistics students, as working on data intermittently may disrupt the flow of interpretation in their research. Financially supported PhD students, often sponsored by their employing universities as part of staff development, therefore predominate the PhD statistics student base (Odhiambo & Onyango, 2018). This scenario calls for robust fundraising to provide scholarships to students.

Factors Facing Supervisors

Lecturers face a substantial challenge of work overload, preventing them from providing adequate guidance to students in their research (Egan et al., 2009). Work overload is further aggravated by insufficient numbers of lecturers. The staff-to-student ratio in mathematics and statistics fields in Kenya has in the past been reported as 1:29 (Mukhwana et al., 2016). This report also highlights the gender imbalance among senior lecturers and professors, with limited representation of female faculty members. The report further states that there were 40 male and 4 female Senior Lecturers and 43 male and 3 female Professors or Associate Professors in 2016. Although the number of students enrolled for statistics or mathematics doctorates was 779 in that year, there were only 35 PhDs awarded between 2012 and 2015. This suggests that only one student graduated for every 2.5 lecturers that could supervise a PhD student in statistics or mathematics. The figures above also show that there were only seven potential female supervisors for PhDs in mathematics or statistics. The gender imbalance may not have changed much given the scarcity of female students studying mathematics and statistics, and sciences in general. This imbalance may be a hindrance to attracting potential female PhD students to study statistics.

The shortage of potential supervisors, combined with heavy workloads and gender imbalances, is not the only challenge facing lecturers. Inadequate and/or inappropriate supervision skills, for example, the inability to mentor students, are also identified as a hindrance to effective supervision. Workshops conducted at Maseno University in 2018 emphasized the need for improved supervision skills, including soft skills, project management, financial management, and curriculum development (Maseno University, 2018). The current low student-to-lecturer ratio calls for the use of more efficient supervision approaches like the cohort model (de Lange et al., 2011). The cohort model will enable concurrent supervision of more students as part of a research group.

Statistics departments in Kenya, typically led by professors and lecturers with a mathematical background, tend to prefer hiring statisticians with undergraduate degrees in mathematical fields. This preference narrows the pool of qualified statisticians available to academia, limiting the development of potential mentors for future statisticians. For example, applied statisticians whose research cuts across theory and practice, are typically not employed in these departments because their first degrees are usually not in mathematics or statistics. The applied statisticians include agricultural statisticians, epidemiologists and financial statisticians, all who can provide invaluable mentoring in their fields of practice. Mentorship plays a crucial role in the employment and successful career advancement of PhD statistics graduates (Munene, 2024). Gatfield (2005) and Lee (2008) emphasize the significance of mentoring skills among supervisors while Hassad (2010) proposes certification of faculty to serve as supervisors. The growing demand for such skills is evident in Kenyan universities' efforts to equip lecturers with supervision and mentoring skills (Maseno University, 2018; AMREF, 2024).

Challenges in the University Environment

The scarcity of resources in Kenyan universities reduces the efficiency of student learning (Obwogi, 2011). For example, dedicated computers for postgraduate students are not readily available in many institutions. Students often have to buy their

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own computers and acquire software independently, software which is usually expensive and proprietary. This silo-like working approach hinders the formation of research groups with a common workspace, making one-on-one supervision the default. Limited office space further complicates matters, as students and lecturers don't always find suitable spaces for consultations. Inadequate resources negatively impact effective service delivery by lecturers (Obwogi, 2011). The Kenyan government's reduced funding to public universities further exacerbates the situation (Wanzala, 2018a).

Inadequate investment in physical infrastructure in Kenyan public universities by the government necessitates innovative approaches to fundraising. Collaborations with established foreign universities and international research institutes with local satellite research centres offer potential avenues to enhance the student learning experience. The European Union's provision of competitive funding for joint research projects between European and African universities facilitates student and lecturer mobility, promoting attachment to advanced research facilities in Europe (European Commission, 2023). Further innovations required include investments in either fully online or blended doctoral programmes in statistics (Jiang et al., 2019). Universities like Euclid (EUCLID, n.d.) have a fully online PhD in biostatistics. Online programs, then, are expected to minimize the need for investing in physical lecture rooms and offices.

Models of Training and Supervision

Two primary models have been employed in the training of statistics doctoral students: (i) the American coursework, research, and thesis model, and (ii) the Humboldtian research and thesis model. The American model involves appointing a team of three to four supervisors, two years of coursework covering theoretical aspects and practical skills, followed by two years of research, thesis writing, and defence (Botha, 2018). The coursework imparts the student knowledge to overcome liminality and comprehend threshold concepts (Kiley, 2017). In contrast, the Humboldtian model follows a research and thesis approach, expecting students to already possess a strong foundation in mathematics and statistical theory before admission. Students in this model spend the initial six or so months on proposal writing guided by one or two supervisors and dedicate two and a half years to research, thesis writing and defence. Students pursuing studies in either model are expected to possess programming skills in statistical software and in a generic computer language like C+ or Visual Basic.

Proficiency in mathematics typing software is also essential. However, not all students meet these expectations, especially those pursuing doctorates using the Humboldtian model. The American model incorporates programming skills training as part of its coursework. Often, Kenyan university curricula are outdated and do not incorporate current trends in the application of theory and new software. Any deficiencies in software skills must be addressed independently, often without guaranteed support from the supervisor. Training in such software is costly and potentially prohibitive. Typically, the American model has six months less of research compared to the Humboldtian model. Students in the Humboldtian model, on the other hand, have to put in extra effort to overcome liminality, the process of crossing conceptual thresholds (Olaniyi, 2020). Kenyan universities predominantly follow the Humboldtian model, which has an apprentice supervision approach. However, there is a growing consideration to adopt a hybrid of the Humboldtian and American models, with some universities transitioning to one-year coursework and two to three years of research format (Wanzala, 2018b).

Joint research and co-supervision with non-academic institutions are increasingly being promoted by scholarship donors. Universities with linkages to international research institutes, such as the African Population and Health Research Council (University of Nairobi, n.d.) or the Kenya Medical Research Institute-Wellcome Trust facility (KEMRI-Wellcome Trust, n.d.), provide students with opportunities for exposure to industry and training on relevant and practical aspects of research thus enhancing their chances of success (African Institute for Mathematical Sciences [AIMS], 2022). In such cases, a scientist from industry or a research institute may act as a co-supervisor through an industry fellowship awarded to the student.

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Implications of this Study

Results from this review raise two fundamental issues that, if addressed, could improve the training of PhD statistics students not only in Kenya but also in other resource-challenged African countries. Firstly, research to develop appropriate training models is still nascent. African scholars in pedagogy need to generate training and supervision models that consider resource scarcity while still assuring high-quality doctoral graduates in statistics. Secondly, the body of knowledge sufficient for a PhD in statistics who has the capacity to solve practical problems with limited resources requires a rethinking of the current curriculum. These issues affect practically all departments of statistics in Kenyan universities and need to be addressed.

CONCLUSIONS AND RECOMMENDATIONS

While the typical PhD statistics students in Kenya possess a strong mathematical foundation acquired during their undergraduate and master's studies, it is mostly adequate to serve up to the master's level. The outdated curriculum often hinders their ability to apply theoretical knowledge to identified research problems at the doctoral level. A crucial step forward involves updating the curriculum. Such changes could benefit from the participation of industry players or professional bodies such as the Kenya National Statistical Society, to ensure objectivity. A significant number of Kenyan lecturers lack robust supervision skills, resulting in a lack of world-class mentoring experiences for students. To address this issue, it is recommended that universities invest more in training and certifying lecturers to become effective supervisors, including supervision of online students. Also, upgrading to increasingly robust and affordable internet service will offer opportunities for universities to train and supervise virtually thus reaching more learners. The current challenges in doctoral training also require universities to adopt new supervision approaches like the cohort model to synergize expertise. Thirdly, the insufficiency of infrastructure and facilities is a prevalent challenge in statistics departments across Kenya. One way of addressing this challenge is to conduct joint research and co-supervise with non-academic research institutions. Although there is no instant solution to limited funding, a sustained commitment to aggressive fundraising efforts can eventually lead to substantial improvements in facility resources and the availability of scholarships for students. This study specifically focuses on four fundamental factors influencing the quality of supervision for PhD statistics students, primarily within the realms of human characteristics and course delivery. However, there may be numerous unexplored factors, and a more comprehensive investigation could uncover new dimensions or redefine existing relationships in the conceptual framework.

Research Limitations

The scarcity of publications specifically addressing the supervision of doctoral students in statistics was a limitation of this study. Additionally, the study did not undertake an empirical survey to provide a more detailed description of the Kenyan situation.

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Conflicts of Interest

The authors declare no conflict of interest.

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