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Hindrances to undergraduate students' meaningful learning of bivariate normal distribution at a Kenyan university

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Abstract

The problem of the study was to investigate hindrances to undergraduate students' meaningful learning of bivariate normal distribution (BND) at a Kenyan university. The study was informed by students' poor performances in BND. This study adopted a case study design and a qualitative research methodology. Data was collected using a questionnaire from second and third-year undergraduate statistics students (n=175). The data was thematically tabulated and analyzed using descriptive statistics of frequencies and percentages. The study revealed various hindrances to undergraduate students' learning of BND, which include poor foundational knowledge of BND, negative attitude towards BND, lack of interest in BND inadequate learning resources, inability to learn the long and complex statistical equations, inability to comprehend BND function, inability to derive the conditional mean and variance equations of a joint distribution, BND not taught in depth, few worked examples and assignments on BND. Based on the findings recommendations are made.

Keywords: Bivariate Normal Distribution, Kenyan University, Meaningful Learning, Statistics

Introduction

Kenya's basic and higher learning institutions places much emphasis on mathematics as a subject and other science subjects, namely; biology, chemistry, and physics to help achieve the country's Vision 2030 objective. The Vision 2030 is a national long-term development blueprint to create a globally competitive and prosperous nation with a high quality of life by the year 2030. The vision aims to transform Kenya into a newly industrializing, middle-income country providing a higher quality of life to all its citizens by 2030 in a clean and secure environment (Government of the Republic of Kenya, 2007).

The Ministry of Education in Kenya stepped up efforts over the years to improve students' performance in mathematics in basic education which had declined. These efforts included collaboration with JICA (Japan International Cooperation Agency) and the establishment of SMASSE (Strengthening of Mathematics and Science in Secondary Education) to improve the teaching of mathematics and hence improve students' performance in mathematics. SMASSE is the in-service training of serving teachers in mathematics and science in secondary schools in Kenya. The poor performance in Mathematics and Science was a matter of serious concern to education stakeholders and the Kenyan government.

Students who perform below average in mathematics in O-level examinations (KCSE) experience difficulties in joining lucrative and marketable degree courses in the universities through KUCCPS (Kenya Universities and Colleges Central Placement Service). KUCCPS is a Kenyan state corporation that provides career guidance and selects students for admission in various courses in various public and private universities. University admission is hugely contested because of the limited chances available for degree courses and constrained facilities in different faculties in the university. Most students do not meet the minimum requirements on cluster points for career placement by KUCCPS, due to poor grades in mathematics at the O-level.

Currently, the Kenyan government is in the process of a curriculum change, by transitioning from the 8-4-4 system (8 years in primary school, 4 years in secondary school, and 4 years in university) which is regarded as examinations-oriented, to the 6-3-3-3 system (6 years in primary school, 3 years in junior secondary, 3 years in senior secondary and 3 years in the university) which is a skill-oriented system. This initiative of changing the curriculum is aimed at simplifying the learning of concepts and gaining skills for a self-reliant citizenry. The students' poor performance in mathematics in basic education compromises the learning of advanced mathematical concepts in higher institutions of learning due to the difficulties they encounter. The difficulties experienced in learning mathematical concepts, especially BND lead to errors which are a direct consequence of students' misconceptions (Sarwadi & Shahrill, 2014) which further hinder the meaningful learning of the content.

This study investigated hindrances to undergraduate students' meaningful learning of BND at a Kenyan university. This was done to seek possible ways of overcoming hindrances to students' learning and performance on the unit covering BND. The students' inadequate proficiencies as evidenced by poor performance in solving BND problems (Onyancha & Ogbonnaya, 2022), is as a result of the difficulties they experienced in learning BND.

According to Bertsekas and Tsitsklis (2002), a bivariate normal distribution is a joint normal distribution of two dependent randomly distributed variables. BND is covered by second-year undergraduate students pursuing statistics courses at a Kenyan university. A joint probability density function, $f(a,b)$, for two random variables, A and B, is given by;-

$$f(a,b) = \frac{1}{2\pi\sigma_a\sigma_b\sqrt{1-\rho^2}}\, e^{-\frac{1}{2(1-\rho^2)}\left\{\left(\frac{a-\mu_a}{\sigma_a}\right)^2-2\rho\left(\frac{a-\mu_a}{\sigma_a}\right)\left(\frac{b-\mu_b}{\sigma_b}\right)-\left(\frac{b-\mu_b}{\sigma_b}\right)^2\right\}}$$

BND forms an advanced statistical concept of the normal distribution which according to Gordon (2006) is useful in psychological research and other scientific applications.

Just like the normal distribution, BND with two random and normally distributed variables is equally important in scientific applications and practically applicable in our day-to-day life situations. For example, in relating the series of marks scored in two statistical units by several university students in a given year of study, the sales profit and expenses of a business entity in a given year, the ages or weights of husband and wife in a sampled married couple, etc.

The BND function is long and has five parameters and two constants. This makes it appear complex, making its learning difficult and thereby hindering students' learning of the concept. At various levels of education, statistics is generally challenging to students (Lugo-Armenta & Pino-Fan, 2021). A few studies, for example, Shojaie et al. (2012), explored the difficulties encountered by students in learning BND and identified that students have difficulties in finding the joint distribution of a function and calculating the bivariate expectation of a variable. These difficulties hinder meaningful learning of BND. The hindrances to students' learning of BND are yet to be fully researched and addressed. It is against this backdrop that this research study was conducted to seek and address possible hindrances to students' meaningful learning of BND.

Theoretical Background

Different factors influence meaningful learning of mathematics. Students' hindrances to learning mathematics result from the difficulties they experience in learning and understanding the concepts. Generally, students encounter difficulties in learning BND and finding the joint distribution of a function, and calculating bivariate expectations (Shojaie, Aminghafari & Mahammadpour, 2012). These difficulties hinder students' learning and understanding of advanced statistical concepts. Many statistical ideas and rules are complex, difficult, and counter-intuitive (Ben-Zvi & Garfield, 2004), for example, BND. This makes it difficult to motivate students to engage in the challenging task of learning statistics. Inconsistency in students' performance in statistical courses is a clear demonstration of the difficulties encountered and hindrances to learning BND concepts. Glancy et al. (2017) indicated that students experience difficulties in collecting and making sense of the data they collect from experiments and tests. DelMas and Liu (2005) showed that part of students' difficulties in variability stems from their misunderstandings of how to represent variability graphically.

Students' negative attitude (Koparan, 2015) towards some statistical concepts hinders their learning and understanding of the concepts. A negative attitude towards statistics learning is having an unfavorable response or disposition to learn statistics (Chiesi & Primi, 2009). Students' negative attitude towards statistics may stem from the difficulties and experiences they had in their earlier foundational statistical concepts. Garfield (1995) acknowledged that teaching statistical courses is challenging because the courses serve students with varying backgrounds and abilities, many of whom have had negative experiences with statistics and mathematics. It is important to note that undergraduate students' attitude towards statistical courses, especially the BND influence their learning and understanding. Some statistical concepts and equations are difficult to comprehend and reproduce when examined because the

concepts seem complex to students. McGrath, (2014) indicated that students described the difficulty of understanding mathematical concepts compared to doing the mathematics questions. According to Nardi (2007), the mathematics taught at many universities consists largely of theorems and their proofs, which students tend to memorize with little understanding, and when required to prove a theorem the students simply regurgitate the proof. Such concepts need regular revision for effective and meaningful learning and understanding.

Students' poor foundational knowledge of statistics hinders their learning and performance in advanced concepts in statistics. Ben-Zvi and Garfield (2004) observed that students' difficulties with the underlying basic mathematics interfere with their learning of the related advanced statistical concepts. Koparan (2015) similarly observed that students' difficulties in understanding the concept of variance hinder their learning of statistics. A firm background in statistical conceptual knowledge necessitates the learning of advanced statistics. Sarwadi and Shahrill (2014) acknowledged that learning mathematics effectively involves building on prior knowledge and integrating different skills and basic concepts to achieve mastery of mathematical calculations and procedures.

A lack of interest among undergraduate students in learning statistics is a setback to their understanding of statistical concepts. Tishkovskaya and Lancaster (2012) indicated that students' lack of interest or inadequate effort in learning mathematics can impact negatively their effective learning of mathematics content. The use of technology in teaching and learning statistics content may help some students build interest and work harder to understand the content well but it can as well interfere with the student's ability to attend to the complexity of some statistical concepts (McGrath, 2014).

Methods

The study adopted a case study design and a qualitative research methodology. A qualitative case study design was used because it allows the researcher to conduct an in-depth study of a case or multiple cases in its natural setting (Creswell & Poth, 2018). Qualitative research explores and understands the meaning of a problem; which involves emerging questions and procedures, collecting data, analyzing the data inductively, building from particulars to general themes, and making interpretations of the meaning of the data (Creswell, 2003).

The study targeted undergraduate statistics students who had completed BND covered in probability and statistics III units in a Kenyan university. Second- and third-year undergraduate students (n=175) were purposefully sampled for the study. A student open-ended questionnaire that sought the students' views on the hindrances to their meaningful learning of BND was used to collect data for the study. The data collected were thematically analyzed in which major themes which directly pointed to undergraduate students' setbacks to learning BND were identified. The themes were further treated using descriptive statistics of frequencies and percentages. Themes with greater frequencies and/or percentages were singled out as a major impediment to students learning of BND. These themes highlighted key hindrances to students' learning of BND in the Kenyan university.

To follow ethical code of conduct in carrying out the research, the first author sought and obtained permission from the Kenyan university to conduct the study. Permission was also obtained from the South African University ethics committee where the first author was registered as a postgraduate student. During data collection, the first author informed the participants of the aim and importance of the study, the procedure of administering the questionnaire, the signing of informed consent forms, and their rights to participate or withdraw from the study even after consenting. The students were also informed that participation in the study was voluntary. Measures to protect students' identities against exposure were assured by the first author, and this was achieved by assigning random numbers to all questionnaires used in the study. The students were as well assured of strict confidentiality to any information they provided and that no information regarding them would be disclosed to any individual or organization.

Results and Discussion

The study findings revealed that students encounter various hindrances to learning BND. Table 1 below illustrates the major hindrances identified with their respective frequencies (percentages).

Table 1. Factors that hinder students' learning of BND

Hindrances to undergraduate students' meaningful learning of BND	No. of students (%)
Inability to learn the long and complex equations in statistics	168 (96.00%)
Inability to comprehend BND function	165 (94.29%)
Poor foundational knowledge of BND	152 (86.86%)
A large number of students in a statistics class	135(77.14%)
Inability to derive the conditional mean and variance equations of a joint distribution	133 (76.00%)
Negative attitude towards learning BND	101 (57.71%)
Lack of interest in learning BND content	90 (51.43%)
Poor teaching of BND and lack of adequate worked examples on BND	83 (47.43%)
Inadequate learning resources on BND	75 (42.86%)

Inability to learn the long and complex equations in statistics

The study showed that the undergraduate students' inability to learn the perceived long and complex statistical equations hindered their learning of BND. Almost all the participants (168 students representing 96.00%) were of the view that the statistical equations are long and complex and that hindered their learning of BND. BND function and other statistical equations seem long and complex, as noted by Ben-Zvi and Garfield (2004), to learn and comprehend. This is possibly due to students' lack of understanding of the parameters or constants which form the equations and the application of the statistical equations. This challenges students and makes the concepts difficult for them to understand.

Inability to comprehend BND function

The study also showed that the undergraduate students' inability to comprehend BND function was another hindrance to meaningful learning of BND in the Kenyan university. A total of 165 students representing 94.29% believed that the many parameters and constants in the BND function make its learning, understanding, and analysis challenging. This hinders effective. The BND function is in the form of:

$$f(a,b) = \frac{1}{2\pi\sigma_a\sigma_b\sqrt{1-\rho^2}}\, e^{-\frac{1}{2(1-\rho^2)}\left\{\left(\frac{a-\mu_a}{\sigma_a}\right)^2 - 2\rho\left(\frac{a-\mu_a}{\sigma_a}\right)\left(\frac{b-\mu_b}{\sigma_b}\right) - \left(\frac{b-\mu_b}{\sigma_b}\right)^2\right\}}$$

$$Where, \mu_a = E(X), \mu_b = E(Y), \sigma_a, \sigma_b \text{ are standard deviations of } A \text{ and } B \text{ respectively}$$

$$\rho = Cor(a,b) = \frac{V_{ab}}{\sigma_a\sigma_b}, \qquad 0 \le a \le \infty, \qquad 0 \le b \le \infty, \qquad \sigma_a, \sigma_b > 0 \text{ and } -1 \le \rho \le 1$$

The variables A and B are dependent and randomly distributed since they are correlated (ρ).

The BND function looks complex and is one of the longest equations in statistics covered by second-year undergraduate students, and needs adequate time to learn and comprehend. The equation has five parameters and two constants for two random variables. The students misconstrue BND equation with its parameters and constants to be complex and thus difficult to learn and understand. This study agrees with Ben-Zvi and Garfield (2004) studies who indicated that many statistical ideas and rules are complex, difficult, and counter-intuitive. Though not all long equations are necessarily complex and difficult to learn and understand, Statistical equations become easy when all their parameters and constants are understood rather than when memorized.

Poor foundational knowledge of BND

The study also found that students' poor background knowledge of BND hinders their learning of BND. As acknowledged by Garfield (1995), this study showed that 152 undergraduate students representing 86.86% opinionated that inadequate foundational knowledge of the mean, variance, standard deviation, normal distribution, marginal distribution, exponential differentiation and integration (used in deriving conditional mean and variance) hindered their learning of BND. Adequate pre-requisite statistical knowledge contributes to effective learning of BND. And a solid statistical foundation enables students to build confidence in their learning of BND leading to enhanced understanding which further simplifies the learning of statistical concepts. Learning is a process, and it is done better when concepts are learnt from the simple to the complex. It is prudent that undergraduate students learn and understand shorter and simple statistical equations with few parameters and constants, for example, the normal distribution equation, before learning longer equations with more parameters and constants, for example, the BND function. Adequate background in statistical concepts is essential for the derivation of the conditional mean and variance equations of a joint distribution.

A large number of students in a statistics class

The study indicated that a total of 135 students (77.14%) were of the opinion that a large number of students in the class inhibited their learning of BND. This is possible because the lecturers' teaching and chalkboard illustrations were not visible to many in the large and often overcrowded classrooms, particularly to those sitting in the back seats. With too many students in the class, students might not have the opportunity to actively participate in the classroom activities and the lecturer might not be able to give individual attention to students who do not understand the concept being taught. This finding is similar to some previous research findings that large class size hinders students student active participation in class and meaningful learning (Ballen et al, 2019; Dejene, 2019; Meaders et al, 2019).

Inability to derive the conditional mean and variance equations of a joint distribution

The study also showed that the students' lack of ability to derive the conditional mean and variance equations of a joint distribution using the BND function hindered the learning of BND. A total of 133 students representing 76.00% were of the opinion that long derivation of conditional mean and variance equations was a major hindrance to learning of BND. The long derivation involves numerous steps, which to some students is complicated to follow and comprehend. The students' wrong perception of the derivation of the conditional mean and variance equations causes a setback in learning of BND.

This derivation is a common problem for undergraduate students. The students experience difficulties in comprehending the derivation and using the derived equations in proficiently solving BND problems (Onyancha & Ogbonnaya, 2022). This study agrees with the findings of Shojaie et al. (2012) which showed that the students had difficulties in finding the joint distribution of a function and calculating bivariate expectation and complex integrals.

Negative attitude towards learning BND

Another hindrance to students' learning of BND was their negative attitude towards the content. A total of 101 students representing 57.71% believed that their negative attitude towards learning BND negatively impacted their learning, understanding, and performance on BND. This study conforms to the finding of Koparan (2015). Students who have a positive attitude to statistical equations and concepts will enjoy learning statistics and consequently build a firm foundational knowledge for learning advanced statistical concepts.

Lack of interest in learning BND content

The lack of interest forms another setback to the undergraduate students' learning of BND. Learning happens only when students are interested. As acknowledged by Mbugua et al. (2012) and Tishkovskaya and Lancaster (2012) findings, this study showed that a total of 90 students (51.43%) asserted that their lack of interest hugely hindered their learning of BND. The students' lack of interest in learning BND will negatively impact their attitude toward the topic

and consequently their learning achievement in statistics in general (Ajisukmo & Saputri, 2017; Awoniyi & Ogbonnaya, 2022).

Poor teaching of the BND and a lack of adequate worked examples on BND

Additionally, poor teaching of BND concepts and a lack of adequate worked examples on BND were cited by the students as a hindrance to their meaningful learning of BND. A total of 83 students constituting 47.43% believed that poor teaching and inadequate examples on BND hindered their learning of the content. The lecturers' method of teaching must be incorporated with chalkboard illustration and integrated with ICT to effectively teach BND. This is because of the long BND equations and the derivation of the conditional mean and variance equations involved. Adequate examples and illustrations on BND will likely improve understanding of the concepts. Few examples on BND make learning and understanding of BND difficult thereby hindering meaningful learning of BND.

Inadequate learning resources on BND

The lack of adequate learning resources e.g., reference books hindered their learning of BND at the Kenyan university. This was asserted by 75 students translating to 42.86% that inadequate learning resources on BND at the university negatively hampered their learning. This conforms to the findings of Mbugua et al. (2012). Most undergraduate students depend on their lecturers' notes and do not have access to more learning resources.

Conclusion and recommendations

This study explored hindrances to undergraduate students' learning of BND in a Kenyan university. The hindrances identified include students' inability to learn the long and complex equations in statistics, lack of interest and negative attitude towards learning BND, poor foundational knowledge of BND, and a large number of students in the statistics class. To counter these hindrances, the authors propose the use of students' group discussions on BND to improve their learning and understanding. Furthermore, the authors suggest the integration of ICT with the teaching of BND to improve student learning of the concept. Also, the authors recommend that lecturers give more worked examples and assignment questions on the normal distribution and the BND to enhance students' learning and understanding.

One limitation of this study is that data were collected from only students and one institution. Hence, future studies may use other sources of data for example, students' notes and examination scripts on BND to gain more insight into the possible reasons for the hindrances students encounter in learning BND. Also, future research studies may explore the hindrances to students' learning of BND in more than one institution. The study findings could be useful to future researchers studying setbacks to the learning and teaching of statistical concepts. The findings might also be found useful by statistics lecturers at various institutions of learning within and outside Kenya.

It is recommended that undergraduate students utilize free internet resources provided by the university to bridge their statistical content and pedagogical knowledge gaps. The use of online resources such as tutorial notes, you-tube videos, math world, etc., can help simplify learning and understanding of BND and boosts students' confidence in statistical concepts. The use of technology in learning and teaching statistics, particularly BND, can help students to develop an interest and improve their learning and understanding of the concepts. It is also recommended that in-depth teaching and learning of BND accompanied by many worked examples and assignment questions should be embraced to enhance learning and understanding of BND. Furthermore, it is recommended that more emphasis should be placed on teaching and revising basic statistical concepts to enable undergraduate students to learn and internalize advanced statistical concepts, for example, BND, with ease.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Additionally, the authors have completely covered the ethical issues; including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies.

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