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The Impact Of Statistics Transposition On Pedagogical Content Knowledge (PCK) Of Teachers At University Center Of Tipaza (Algeria)

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Abstract:
The present paper analyzes the impact of statistics transposition on pedagogical content knowledge (PCK) variables of statistics' teachers from the university center of Tipaza by comparing two categories of teachers: pre-transposition category and post-transposition category. The evaluation process took place inside classrooms by observing teachers in action during their statistics lessons and recording the score corresponding to each variable. For comparison purposes, a summary statistics for the two categories of teachers and the unpaired t-test were used. In order to analyze the association between PCK variables from one side, and between PCK variables and teachers from the other side, principal component analysis (PCA) was applied. The main results indicate that transposition in statistics teaching had considerably improved the performance of PCK of teachers especially the semiotic, practical and interactional aspects. It has, however, less impact on the improvement of the cognitive and the epistemological aspects.

Keywords: Statistics, Didactics, Knowledge, Teachers, Algeria

Introduction:

In the last few decades, statistics started witnessing a huge development that fast expanded to other tracks namely data science and artificial intelligence. This has been boosted by the huge technological development in terms of computer science and programming software. This latter arose to respond to the growing demand for more enhanced results and more accurate analyses. Teaching of statistics is in the forefront of interests that needs to be adapted to the new aptitudes requirements and to the new teaching methods in order to improve the conceptual understanding from one side (Idris, 2022) and to meet the expectations of the new technological generation of students from another side (Markulin et al., 2022). In light of the all above-mentioned changes that accompanied statistics development, shifting from classical teaching methods to modern ones constitutes a subject of a transposition procedure in statistics that needs to be given a considerable attention (Chevallard & Bosch, 2020).

As many universities in Algeria, statistics transposition at University Center of Tipaza is becoming an imperative imposed by the stronger demand for more qualified teachers from one side, and the accelerated technological development from the other side. In light of these changes, a quick adaptation must be hold by teachers in order to suitly build bridges between the subject matter they are teaching and the pedagogical approaches they are using to teach it (Ball, 2000). In other words, the teachers must demonstrate an ability to relate and integrate their pedagogical knowledge to their subject matter knowledge to ensure conveying knowledge in a suitable and a meaningful way to their students. This means that teachers must demonstrate a strong pedagogical content knowledge (PCK) in their teachings of statistics (Shulman, 1986). The objective of this study is to analyze PCK of statistics teaching at the University Center of

Tipaza in light of transposition in statistics driven by the statistical software panoply as well as the developed programming languages. In this paper, we are seeking to find an answer to the following research question: how does statistics transposition affect PCK of statistics teachers at the University Center of Tipaza?

To answer this question, we structured our research as follows. First, we provide a literature review on PCK components as well as studies highlighting the relationship between transposition in statistics teaching and PCK. Second, we describe materials and methods as well as the methodology followed to analyze and compare teachers' PCK in light of transposition in statistics. Third, we present the study results and we conclude with the discussion of findings.

Literature Review:

Several studies related to our research have been reported in the literature. Starting with PCK review, Cochran et al. (1993) say that PCK could be defined as the integration of four major components including subject matter knowledge, pedagogical knowledge, knowledge about students (their abilities, motivations and prior knowledge) and knowledge about students' environment.

Many studies explored the impact of didactic transposition or one of its components on PCK. The study conducted by Batanero et al. (2004) focuses on the use of technology as a tool to enhance statistical teaching. It shows the importance of developing statistical thinking skills in students and highlights the potential of modern technology in supporting the learning process. Shulman (1986) emphasizes that teachers must be familiar with teaching strategies that facilitate student's learning. He highlights the importance of PCK in improving teaching and learning outcomes and discusses the various components of PCK, such as knowledge of instructional strategies, knowledge of students' prior knowledge, knowledge of students' misconceptions, and knowledge of assessment and feedback. In addition, studies of Grossman and McDonald (2008), and Grossman (1991) discuss the role of didactic suitability on enhancing PCK of teachers. The main idea is that effective teaching requires a combination of pedagogical knowledge, subject matter knowledge as well as knowledge about students. Koehler and Mishra (2009) explored the introduction of technology in PCK, and showed how didactic suitability can enhance the technological PCK of teachers.

Studies of Godino et al. (2007) and Godino et al. (2008) suggest a number of didactic dimensions that help to analyze the PCK of statistics teaching. They concern namely the cognitive, epistemological, semiotic, emotional, practical and interactional dimensions. The cognitive dimension focuses on content adequacy and ensures that this later aligns with students' previous knowledge. The epistemological dimension examines the fundamental nature and characteristics of the statistical concepts taught by teachers. The semiotic dimension focuses on how to represent and communicate statistical ideas to students. The emotional dimension explores the motivational factors that influence both teaching and learning processes. The practical dimension analyzes the statistical tasks and activities that students are engaged in, along with the didactical materials available for learning. Finally, the interactional dimension highlights the dynamics of interactions between teachers and students, as well as among students themselves.

Methodology:

The present study took place at the university center of Tipaza in the period running from January 14th, 2024 to December 15th, 2024. In order to analyze and compare teachers' PCK in light of transposition, 23 teachers of introductory statistics and probabilities from the university center of Tipaza have been selected. In order to show the impact of statistics transposition on PCK among teachers, the selection process took into account the age factor allowing the distinction between two categories of teachers. The first category (individuals from 1 to 10) is considered as a pre-transposition category that concerns teachers who are about to retire, who used to present their lessons based on classical teaching methods of statistics and who often find difficulty to adapt to the new technological developments. The second category (individuals from 11 to 23) is considered as a post-transposition category including young teachers with less than 10 years teaching experience, who used to rely on statistical software when they were students and who often feel more comfortable teaching in light of statistics changes.

The analysis of teachers' PCK is based on different questions (variables) inspired from the PCK's components and didactic dimensions presented in the above literature revue, such that each variable is evaluated by a scale score ranging between 1 (very weak score) to 9 (very strong score) allowing to measure it (appendix 1). PCK analysis was done by the author with the help of two other professors having a strong background in statistics didactics and curriculum studies. After introducing the teachers to the objective of the study and getting their approval, the evaluation process took place inside classrooms by observing teachers in action during their statistics lessons and recording the score corresponding to each variable. For each teacher, the observing duration is the same as duration of the lesson fixed at 90 minutes. To make sure that all PCK dimensions have been evaluated carefully, the evaluation process has been repeated in two more other lessons for each teacher. At the end, the final score corresponding to a particular variable is estimated by taking the average of the three different estimated scores corresponding to that variable. It should be noted that teachers were informed the collected data is only used to fulfill the requirements of the present study.

To get a summary statistics about PCK dimensions for the two categories of teachers, variables scores corresponding to each dimension have been averaged. The unpaired sample t-test was used to compare averages corresponding to the same dimension. To capture additional and more detailed information from our dataset and analyze the association between PCK variables from one side, and between PCK variables and individuals corresponding to the two categories of teachers from another side, principal component analysis (PCA) was applied.

Results and Discussion:
Out of the 23 studied teachers, the average age was 58.7 years (*Std. Dev* = 2.63) for the pre-transposition category and 35.23 years (*Std. Dev* = 4.32) for the post-transposition category of teachers, which indicate a large age difference between the two generations of teachers.
A summary statistics including the average scores ($\overline{X}$) and standard deviations (*Std. Dev*) corresponding to PCK dimensions of the two categories of teachers is presented in table 1.

Table 1. Summary statistics

PCK dimensions	**Pre-transposition teachers**		**Post-transposition teachers**		***t-statistic***	***P-value***
	$\overline{X}$	***Std. Dev***	$\overline{X}$	***Std. Dev***		
Cognitive dimension (CD)	5.93	0.66	5.00	0.60	3.534	0.002

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Epistemological dimension (ED)	6.70	1.19	5.62	0.94	2.443	0.023
Semiotic dimension (SD)	5.98	0.79	6.88	0.58	-3.193	0.004
Emotional dimension (ED)	5.33	0.97	7.26	0.55	-6.040	0.0001
Practical dimension (PD)	5.35	0.66	6.96	0.45	-6.951	0.0001
Interactional dimension (ID)	5.13	0.66	6.56	0.87	-4.321	0.0003

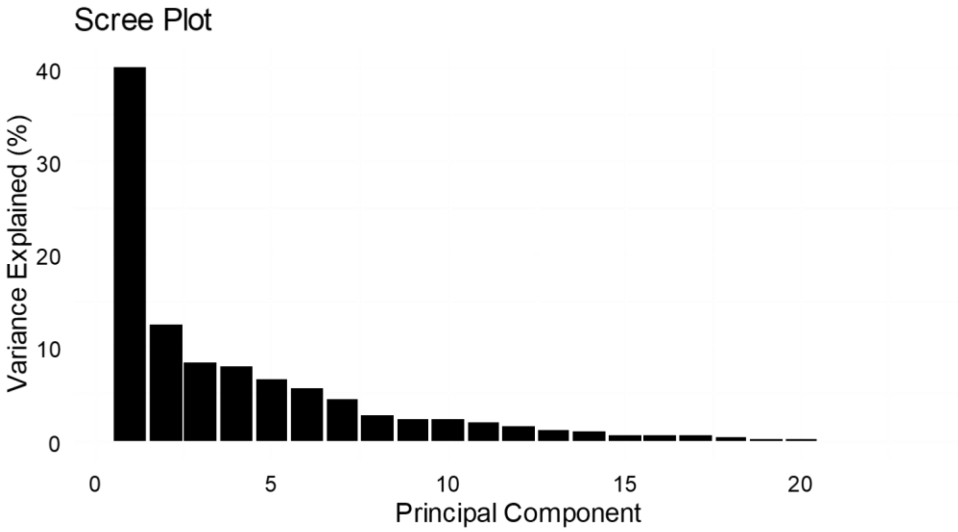
Source: author calculations based on teachers answers to the questionnaire

According to table 1, we notice in general that the average scores corresponding to cognitive and epistemological dimensions are higher in pre-transposition teachers than in post-transposition ones. In contrast, average scores corresponding to semiotic, emotional, practical and interactional dimensions are higher in post-transposition teachers than in pre-transposition ones. At 5% level of significance, t-statistics and P-values indicate that the differences between the two categories of teachers are significant for the different PCK dimensions.
In the following, we display the outputs corresponding to PCA.

- **The scree plot**

The scree plot of the PCA output allows us to decide how many components to retain for analysis by preserving as much as variability as possible of the studied phenomenon.

Figure 1. Scree Plot of PCA output



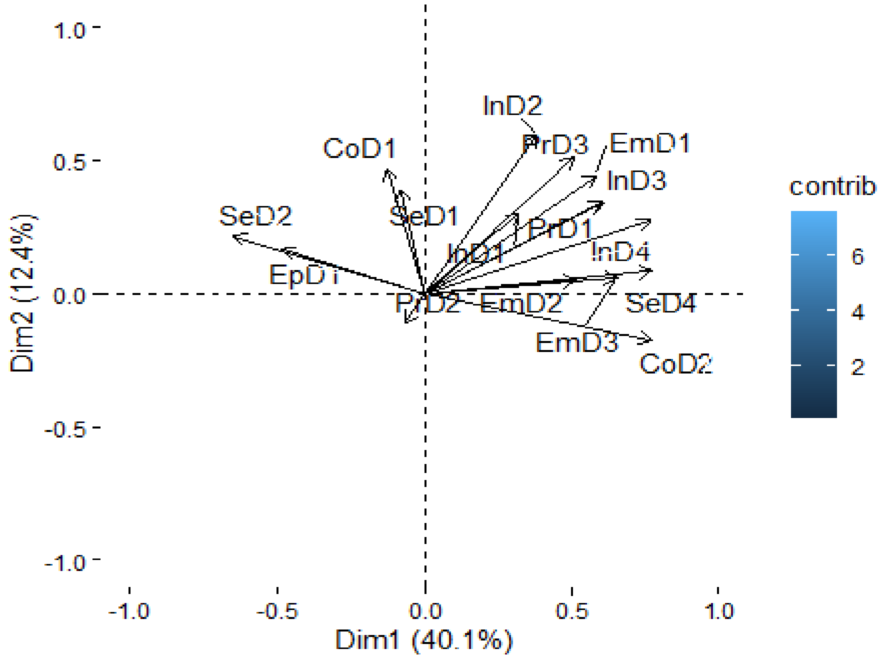
Source: author calculations based on PCA analysis

The scree plot (figure 1) and the summary statistics of the PCA output (appendix2) indicate that the total variance explained by the two first principal components (PC1 and PC2) is equal to 52.54%, which is a good percentage to represent the total variability of the studied phenomenon. As a result, we retain the principal components PC1 and PC2 for the rest of our analysis.

- **Plot of variables**

The plot of variables provides insights about the strength of the relationship between the variable and the principal component (PC). The vectors of variables that have a strong positive or negative correlation with a principal component are pointing approximately in the same or opposite direction as the principal component and are closer to the circle. According to figure 2, we notice that variables that are strongly positive correlated with the first principal component (PC1) are SeD3, SeD4, PrD4, CoD2 and InD4, where variables that strongly negative correlated with PC1 are Age, CoD3, CoD4, EpD2 and EpD3. We have only one variable (CoD1) that is averagely positive correlated with PC2.

Figure 2. The circle of correlation between variables



Source: author calculations based on PCA analysis

It should be noted that variables that are strongly correlated with PC1 and PC2 are more important in capturing the variance represented by those components. The other variables that are average or weak correlated with PC1 and PC2 capture less variance.

- **Plot of individuals**

In the plot of individuals, the distance between points reflects the similarity or dissimilarity between individuals. Individuals that are closer on the plot are more similar in terms of their overall patterns of variation, whereas those that are farther apart are more dissimilar. According to figure 3, we can clearly distinguish between two categories of individuals (teachers) in terms of similarity. The first category lying on the right hand side of the plot gathers post-transposition teachers except for teachers 11 and 12 who are far from the cluster, where the second category lying on the left hand side of the plot gathers pre-transposition teachers except for teacher 1, 4 and 10. This latter tend to share the same characteristics as teachers 11 and 12.

Figure 3. The Plot of Individuals

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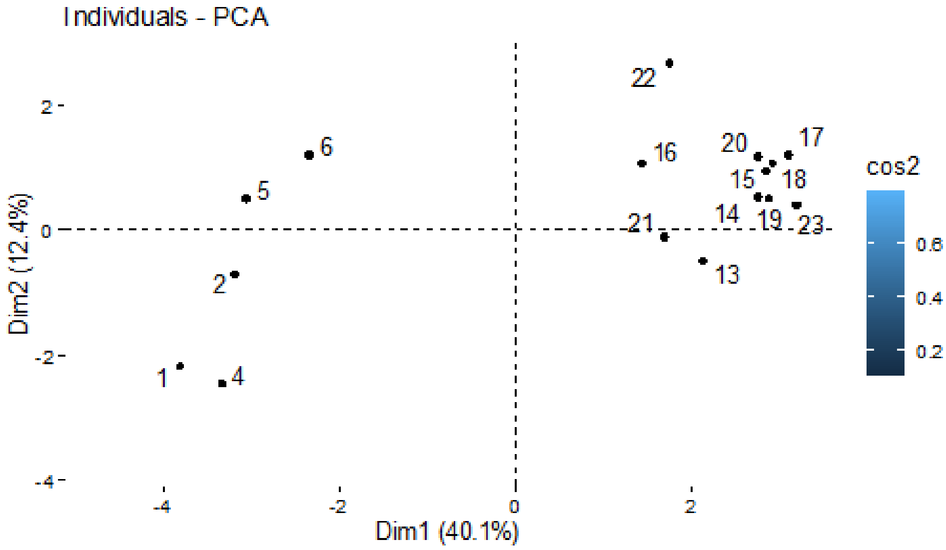
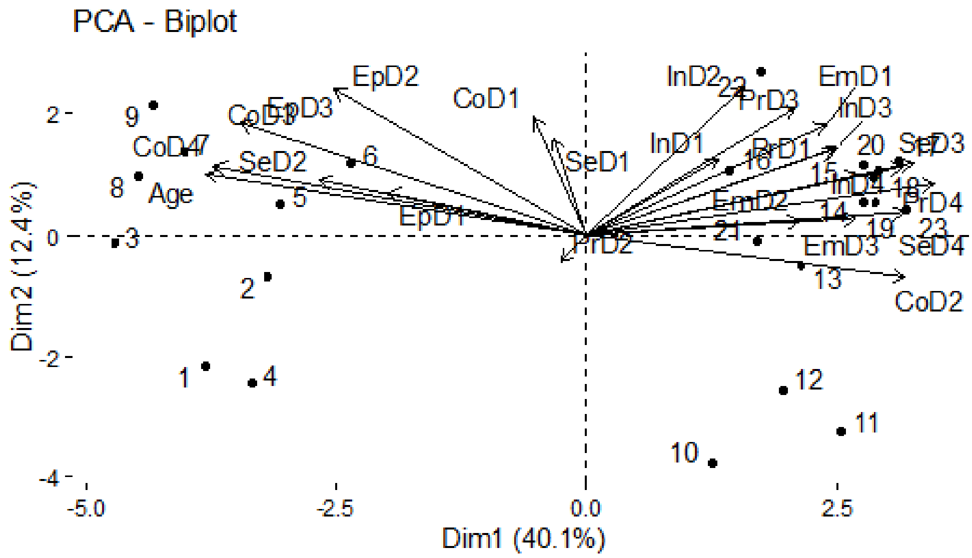


Source: author calculations based on PCA analysis

- **The Biplot**

The Biplot presented in figure 4 combines the plot of individuals (figure 3) with the plot of variables (figure 2). It aims to visualize the relationship existing between individuals (teachers) and variables (questions corresponding to PCK dimensions). The decision rule says that individuals (teachers) who are closer to a particular variable would be more similar to the characteristics presented by that variable.

Figure 4. Simultaneous representation of variables and individuals



Source: author calculations based on PCA analysis

According to figure 4, we notice that the post-transposition category of teachers (except for teachers 11 and 12) is more correlated with variables that are positive strongly or averagely correlated with PC1, where the pre-transposition category is more correlated with variables that are negative strongly or averagely correlated with PC1 (except for teachers 1, 4 and 10). This means that, in general, post-transposition teachers are more efficient than pre-transposition ones in terms of the use of visual aids (SeD3), the use of interactive simulations, videos, and models (SeD4) as well as the integration of digital tools and resources into their teaching practices

(PrD4). They also demonstrate more ability to use various instructional strategies and representations (CoD2) and better interactional abilities in overcoming learning difficulties (InD4). In other terms, post-transposition teachers are showing better abilities regarding variables related to the semiotic, practical and interactional dimensions than pre-transposition ones.
In contrast, pre-transposition teachers demonstrate more proficiency in the cognitive and the epistemological aspects especially the ability to identify common misconceptions and difficulties that students may have about a specific topic (CoD3) and the ability to foster problem-solving and critical thinking skills in their students (CoD4). They are also showing better abilities to adapt their instructional approaches according to the context in which they are teaching (EpD2), to manage classroom dynamics and address common students' misconceptions (EpD3).

Conclusion:
According to our previous analysis, we can say that didactic transposition has a significant impact on pedagogical content knowledge (PCK) of statistics teachers at university center of Tipaza. The main results indicate that transposition in statistics teaching driven by the technological development and statistical software panoply had considerably improved the performance of teachers especially regarding the semiotic, practical and interactional aspects. However, the cognitive and the epistemological aspects are not significantly impacted by didactic transposition especially that those latter are abstract in nature and less influenced by technological changes. They require rather more experienced teachers who are able to identify and deal with the common misconceptions in order to foster students' critical thinking and manage classroom dynamics (Hazzi et al. 2022).
Our results are consistent with numerous studies that highlight the significant influence of didactic transposition on various components of pedagogical content knowledge (PCK). Mayer (2010) precise that didactic transposition plays a vital role in aligning visual aids with learning objectives, thereby enhancing their relevance to the desired learning outcomes. Furthermore, the process of didactic transposition, which involves simplifying and organizing academic content, becomes more efficient when supported by visual displays (Hegarty, 2011). In addition to that, didactic transposition guarantees that interactive simulations and videos are in harmony with particular learning objectives, and thus enhancing their effectiveness as educational tools to reach the desired outcomes (Koh and Divaharan, 2011). In relation to the integration of diverse instructional strategies and representations, Chevallard (1985) highlights the importance of didactic transposition in ensuring their alignment with specific learning objectives. This alignment serves as a valuable tool for instructors in reaching their educational goals. Regarding the impact of didactic transposition on enhancing interactional abilities for surmounting learning challenges, Tomlinson (2001) emphasizes on the importance of differentiated instruction, which involves adjusting teaching methods, content and resources to accommodate different learning styles, strengths and weaknesses among students.
On the other side, a study conducted by Hattie (2003) indicates that experienced teachers, which corresponds to pre-transposition teachers in our study, typically demonstrate a more profound cognitive and epistemological grasp of their subject compared to novice teachers, or post-transposition teachers in our context. A recent study by Hazzi et al. (2022), focusing on the examination of conceptual understanding and reasoning abilities of prospective physics teachers in Algeria, revealed that novice educators often encounter significant conceptual challenges when it comes to grasping the properties and characteristics of covalent bonds. The study suggests that developing a coherent understanding in this regard may require more time

and more experience on their part.
Although the existence of rare studies that indicate a direct relationship between proficiency in statistical software use and good semiotic, practical and interactional skills, there can be many benefits to teachers being proficient in statistical software for teaching statistical concepts. This can be explained by the fact that teachers who are proficient in statistical software manipulation may use those tools to enhance their teaching by providing visual representations of data and simulations, which may help in conveying complex information to students. This, in turn, can be seen as an indirect practice of semiotic abilities. In addition to that, teachers being proficient in statistical software are likely to have a strong grasp of data analysis techniques. As a result, they tend to have more abilities to diversify their explanations and interpretations, which can be beneficial when conducting a research or teaching subjects that require data-driven analyses. In summary, despite its advantageous side for teaching statistical concepts and applications, teachers' proficiency in statistical software does not guarantee an effective teaching alone. An effective teaching requires multiple-form skills that includes technical expertise, pedagogical knowledge, and clear communication regardless of software use. When applied with careful consideration, didactic transposition in statistics teaching can yield favorable outcomes in terms of PCK especially by enhancing students' interactional skills and their capacity to overcome learning difficulties. To deal with the challenges that face PCK in light of didactic transposition, we suggest customizing teaching methods and resources to accommodate various learning preferences, delivering content that is both lucid and accessible, and fostering active and tailored instruction to address the unique requirements of diverse learners.

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Appendix 1

Dimension	Criteria	Code	Score (1 to 9)
Cognitive dimension (CD)	Content adequacy with students' prior knowledge	CoD1	
	Teacher's ability to use various instructional strategies and representations	CoD2	
	Teacher's ability to identify common misconceptions and difficulties that students may have about a specific topic	CoD3	
	Teacher's ability to foster problem-solving and critical thinking skills in their students	CoD4	
Epistemological dimension (ED)	Teacher's ability to effectively present and structure statistical content for his students	EpD1	
	Teacher's ability to adapt his instructional approaches according to the context in which he is teaching	EpD2	
	Teacher's ability to manage classroom dynamics or addressing student misconceptions	EpD3	

Semiotic dimension (SD)	The clarity and coherence of the statistical language being used	SeD1	
	The appropriateness of symbolic representations	SeD2	
	The effectiveness of the visual aids (graphs, diagrams, maps, and images)	SeD3	
	The use of interactive simulations, videos, and models	SeD4	
Emotional dimension (ED)	The creation of a positive and supportive learning environment	EmD1	
	Fostering students' interest, motivation and engagement	EmD2	
	Addressing students' affective needs and attitudes towards statistics	EmD3	
Practical dimension (PD)	The relevance of tasks that students engage in during the teaching and learning process.	PrD1	
	Giving opportunities to students to actively participate and explore statistical ideas	PrD2	
	The alignment of the activities with the intended learning outcomes.	PrD3	
	The integration of digital tools and resources into teaching practices	PrD4	
Interactional dimension (ID)	Providing clear explanations and facilitating discussions	InD1	
	The interaction between the teacher and the students	InD2	
	The interaction between the students themselves	InD3	
	Interactional abilities in overcoming learning difficulties.	InD4	

Appendix 2

```
>library(readxl)
>library(tidyverse)
>library(readxl)
>data<- read_excel("C:/Users/Abdeslam/Desktop/data.xlsx")
>View(data)
>scaled_data<- scale(data[, -1])
>pca_result<- prcomp(scaled_data, scale = TRUE)
>summary(pca_result)
Importance of components:
                          PC1    PC2     PC3     PC4     PC5     PC6     PC7     PC8
Standard deviation     3.0367 1.6917 1.38696 1.34497 1.22859 1.14427 1.00426 0.78851
Proportion of Variance 0.4009 0.1244 0.08364 0.07865 0.06563 0.05693 0.04385 0.02703
Cumulative Proportion  0.4009 0.5254 0.60901 0.68766 0.75329 0.81022 0.85407 0.88110
                          PC9    PC10    PC11    PC12    PC13    PC14    PC15    PC16
Standard deviation     0.7352 0.70944 0.65336 0.58831 0.49915 0.43979 0.36612 0.33634
Proportion of Variance 0.0235 0.02188 0.01856 0.01505 0.01083 0.00841 0.00583 0.00492
Cumulative Proportion  0.9046 0.92648 0.94504 0.96009 0.97092 0.97933 0.98516 0.99008
                          PC17    PC18    PC19   PC20    PC21      PC22      PC23
Standard deviation     0.32746 0.26976 0.17122 0.1270 0.05223 0.0002817 6.664e-17
```

```
Proportion of Variance 0.00466 0.00316 0.00127 0.0007 0.00012 0.0000000 0.000e+00
Cumulative Proportion  0.99474 0.99791 0.99918 0.9999 1.00000 1.0000000 1.000e+00
>pca_loadings<- pca_result$rotation
>variance_explained<- pca_result$sdev^2 / sum(pca_result$sdev^2) * 100
>pca_scores<- pca_result$x
>scree_data<- data.frame(PC = 1:length(variance_explained), VarianceExplained = variance_
explained)
>ggplot(scree_data, aes(x = PC, y = VarianceExplained)) +
+ geom_bar(stat = "identity", fill = "steelblue") +
+ labs(title = "Scree Plot", x = "Principal Component", y = "Variance Explained (%)") +
+ theme_minimal()
```

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