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Modern Multivariate Statistical Methods for Evaluating the Impact of WhatsApp on Academic Performance: Methodology and Case Study in India

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Abstract: Despite the increasing amount of research on social media, there are few studies on the use of WhatsApp to assess academic performance. Surprisingly, students use social media during lectures, causing a problem. According to the literature, students utilize WhatsApp throughout academic activities where it is prohibited. Researchers and policymakers must pay attention to this problem to understand its impact on academic achievement. In this paper, by using multivariate statistical methods, we investigate the impact of WhatsApp use on academic performance. We construct a questionnaire for this investigation and apply it to a case study based on a sample of 258 students of management from India. We determine the prevalence of WhatsApp employment among these students and note that many of them utilize the app for academic purposes. We found a positive association between time spent on WhatsApp and students' grade point average (GPA) based on factor, principal component, correlation, and chi-square analyses. Answering questions on the app in class is related to the program's ability to help students learn. More use of the app in class leads to a lower GPA. However, sometimes, using the app might help students learn and perform better. We identify that many students disseminate materials through the app for academic purposes, contributing to their academic performance. Furthermore, this app is utilized for communicating with their teachers. Computations were carried out with the R and SPSS software.

Keywords: disjoint principal components; education data; grade point average; information and communication technologies; operationalization of variables; social media; multivariate statistics

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1. Symbology, Introduction, and Bibliographical Review

In this section, the abbreviations, acronyms, notations, and symbols used in our work are defined in Table 1. In addition, we provide here the introduction, bibliographical review on the topic about related works as well as the objectives and description of the sections considered in this paper.

1.1. Abbreviations, Acronyms, Notations, and Symbols

Next, Table 1 presents the symbology considered in this paper to facilitate its reading.

Table 1. Acronyms, notations, and symbols employed in the present document.

Acronyms	
Notations/Symbols	**Definition**
DPCA	Disjoint principal component analysis.
FA	Factor analysis.
GPA	Grade point average.
PCA	Principal component analysis.
n	Number of individuals or entities.
p	Number of original, observable or measurable variables.
q	Number of latent variables in a multivariate study ($q < p$).
r	Number of principal components in a multivariate study ($r < p$).
i, j, k, l	Indices.
X_j	Original variable j in a multivariate study.
x_{ij}	Observation of individual i on variable j.
f_k	k-th common factor in FA.
f_{ik}	Score of individual i on k-th common factor in FA.
λ_{jk}	Loading of original variable j on k-th common factor in FA.
u_j	j-th specific factor in FA.
a_{il}	Coordination of individual i on l-th component in PCA.
b_{jl}	Loading of variable j on l-th component in PCA.
c_l	l-th component in PCA.
d_j	Loading of j-th-specific factor in FA.
e_j	Error when approximating variable j.
e_{ij}	Error when approximating observation x_{ij}.
$\boldsymbol{A}$	Score matrix in PCA with elements $a_{il} \in \boldsymbol{A}$.
$\boldsymbol{B}$	Loading matrix in PCA with elements $b_{jl} \in \boldsymbol{B}$.
$\boldsymbol{E}$	Error matrix with elements $e_{ij} \in \boldsymbol{E}$.
$\boldsymbol{F}$	Matrix of entity scores on common factors with elements $f_{ik} \in \boldsymbol{F}$.
$\boldsymbol{I}_q$	Identity matrix of order $q \times q$.
$\boldsymbol{\Lambda}$	Factor matrix in FA with elements $\lambda_{jk} \in \boldsymbol{\Lambda}$.
$\boldsymbol{X}$	Data matrix with elements $x_{ij} \in \boldsymbol{X}$.
$\boldsymbol{X}^\top$	Transpose of matrix $\boldsymbol{X}$.
$\|\boldsymbol{X}\|$	The Frobenius norm of matrix $\boldsymbol{X}$.
$\mathrm{Cor}(X, Y)$	Correlation between variables X and Y.

1.2. Introduction

The internet has infiltrated all aspects of life as a source of information, commerce, and communication. People's communication channels are changing because of social media, which are an outgrowth of internet technology. Social media are helpful ways of communication among people in most of their activities such as economy and education. This occurs especially among students, in the current era of expansion of information and communication technologies [1,2]. WhatsApp, Facebook, Instagram, Telegram, and other social media applications have become incredibly popular and addictive, with their use becoming predictable [3]. In today's world, WhatsApp is employed to exchange data, information, files, images, audio and video, update status, location, send instant messages, and conduct real-time chats without incurring any costs. WhatsApp is widely utilized by young people who value their friendships, social lives, and family relationships [4].

Former Yahoo workers, Brian Acton and Jan Koum, introduced WhatsApp to the market in 2009 with the goal of making multimedia communication easier, faster, and better. To operate WhatsApp, one needs internet access and a phone number at first, but once it is installed, it only requires internet access. Due of the aforementioned factors, WhatsApp has become extremely popular among students. Some of the benefits of utilizing WhatsApp for the students of higher education include improved relationships, increased study motivation, personalized course materials, and the development of collaboration talents [5,6]. This indicates that WhatsApp has the potential to improve students' learning outcomes by allowing them to communicate with one another in real time. WhatsApp's technical benefits are its simplicity, cost, and privacy (in comparison to other social networks).

Studies on students' use of WhatsApp in higher education institutions have been undertaken in countries such as England, Ghana, Malaysia, Spain, and the United States (US). However, the literature reveals that there is an ongoing disagreement about the impact of WhatsApp on students' academic achievement [7–10]. Some researchers believe WhatsApp can help students improve their grade point average (GPA) [11], while others believe it can be addictive and have a negative impact on academic performance [3,12,13].

In this context, one can apply multivariate statistical methods for investigating the impact of WhatsApp use on academic performance based on reviews and responses to face-to-face and online surveys as well as through social media [14]. Such methods are related to factor, principal component (PCA), correlation, and chi-square analyses [15]. We construct a questionnaire for this investigation and apply it to a case study for a sample of 258 students of management from India. Specifically, we add knowledge about the use of WhatsApp and investigate the relationship between WhatsApp and academic performance of undergraduate and postgraduate management students at various universities in India. Note that such students have a different socioeconomic and demographic environment than students from other areas. There has been very little research on the impact of WhatsApp use on academic performance among students. This aspect is particularly of interest in India, given that this country is rising as a viable market with a large young population.

Dehradun is India's education capital. There are five renowned private universities in this city: Petroleum and Energy Study (UPES), DIT, IMS, ICFAI and Graphic Era universities, as well as several institutes that educate the students in the field of medicine, science and technology, management, and laws. Management is a career in which future managers are formed and where teaching involves day-to-day problems, real case studies, and real-life managerial skills. Therefore, the utilization of WhatsApp is more advantageous for management students as compared to students from other areas.

The present study's findings can explain how WhatsApp use facilitates or hampers students' learning, permitting us to implement some policies. Our study contributes to the literature establishing why the use of WhatsApp can affect the academic performance of the students. Furthermore, this study adds value determining how the employment of WhatsApp can be stated as a platform where students and faculties can share their academic stuffs, allowing each other to manage and discuss diverse aspects. These aspects can be notes, pictures, assignments, paper patterns, important links of academic contents, and lecture videos [16]. In addition, we also propose a methodology that can be used by researchers when they need to carry out a dimension reduction for a high number of variables, facilitating the interpretation and characterization of latent dimensions.

1.3. Literature Review on WhatsApp Usage

Communication between students as well as among students and their teachers has become digitalized currently, using various modes of communication such as email, short message service, Facebook, and WhatsApp [17]. Each of these modes has unique qualities that influence its suitability for teaching and learning [18]. Teachers and students in higher education institutions have been utilizing WhatsApp as a new form of communication. Several authors [19–21] investigated the impact of mobile phone/social media use on the teaching–learning process, finding both good and negative effects; see also [22].

In [11], it was stated what students confront when utilizing WhatsApp [23,24]. The literature's findings indicate that WhatsApp has been domesticated among young people. According to these findings, undergraduates gain from employing WhatsApp for discussing and sharing study material and information. Such findings conclude that the undergraduates encountered serious problems because of the use of WhatsApp, such as distractions and exposure to unfiltered messages or material.

In [25], the WhatsApp usage was analyzed among postgraduate students in a university setting in Karnataka, and the researchers discovered that most postgraduate students employed WhatsApp for educational purposes. According to these findings, students who utilize WhatsApp for educational purposes on a regular basis improve their academic performance.

In [26], a study was conducted on the use of WhatsApp and university students' perceptions on the potential integration into their education. The author discovered that students mostly utilize WhatsApp to maintain permanent contact with family and friends as well as to share media and other data. Students also employ WhatsApp to share course-related announcements, to require help from previous students, and to manage links to topics and course-related materials. The author concluded that students disagree that WhatsApp is an issue for their education, and that if it was introduced, they would have positive thoughts and intents about utilizing WhatsApp in their formal learning.

In [27], the impact of WhatsApp was analyzed on academic achievement among medicine students. According to this work, there is no relation between WhatsApp utilization and student academic achievement. WhatsApp was discovered to be employed by 99% of the respondents, with over 53% of them using it for academic purposes.

In [28], 332 Spanish university students were analyzed in an observational and descriptive study. According to the reported results, students have a high level of reliance on WhatsApp, with 97% of pupils using it more than ten times per day. The authors discovered that WhatsApp has a negative impact on student achievement.

The use of social media in higher education has been a source of concern for researchers [29,30]. Note that 493 students were analyzed [31] to understand the impact of WhatsApp use on undergraduate academic performance in Ghana. The authors had two objectives: (i) to determine the impact of sociodemographic characteristics on study time allocation [32]; and (ii) to state the impact of WhatsApp on students' academic performance using GPA. According to the findings [31], as the time devoted to studying increases, her/his academic accomplishment increases as well. The authors [31] discovered that using WhatsApp has a beneficial impact on students' academic performance based on a regression model.

In [33], the function of WhatsApp in promoting learning among medicine students was investigated. The author selected 82 students of medicine, who own smartphones and use WhatsApp [34–36]. Students were also classified as slow or quick learners based on their performance on the first semester assessments. It was concluded that employing WhatsApp boosts slow learners' knowledge by piquing their attention as well as their academic achievement. In [37], an investigation on how WhatsApp can help students to improve their GPA was performed. Using connectivism and satisfaction theories, the authors discovered that students utilize WhatsApp to a moderate extent. They discovered a relation between students' use of WhatsApp and their academic achievement. According to the findings, students should aim to employ WhatsApp as much as possible to help them with their studies. Even though countless studies have been undertaken on the subject, these studies have some flaws.

1.4. Objective, Contribution, and Description of Sections

Our study fills a gap in the literature on using WhatsApp in academic activities, its impact on academic performance, and an examination of this problem in India. Our investigation discusses the use of social media and behavior thinking. We explore the effect of social media on the knowledge enhancement in a case study of management students in private universities of India. We evaluate the effect of social media on academic performance when employing WhatsApp during academic activities. Although the use of WhatsApp was investigated in [16] for academic purposes, our study focusses on different domains and contexts, employing an efficient text document clustering approach by means of a multi-search arithmetic optimization algorithm instead of how it was utilized in [38].

Our study also contributes to theoretical premises related to the satisfaction theory, which dominates social media usage and behavior thinking [39]. This theory considers social media to be a tool for gaining knowledge as well as a source of social contact and distraction for users. According to this notion, a user's favorite social networking platform can become deeply entwined with them, much like an addictive substance. It is based

on the notion that this addiction affects the academic students' performance who employ social media, notably WhatsApp, during their academic activities.

The research questions to be addressed are as follows: (a) Is there a connection between WhatsApp usage and academic performance? (b) How much does WhatsApp have an impact on academic performance? Our main objectives are: (i) to propose a methodology for evaluating the impact of WhatsApp use on academic performance based on a new questionnaire and modern multivariate statistical methods; as well as (ii) to apply this methodology to a case study of management students at private universities in Uttarakhand, India. This study can aid in the development of rules and regulations for students' use of mobile phones and social media during academic activities.

The remainder of this article is structured as follows. In Section 2, we present the methodology to be used. Section 3 applies the methodology to a case study in India. In this section, we provide an algorithm that summarizes the methodology proposed in our research. Some conclusions are discussed in Section 4, and here also are provided some limitations and ideas about future research.

2. Methodology

In this section, we present the methodology to be used including academic performance, data source, data collection, field work, and modern multivariate statistical methods for dimension reduction.

2.1. Academic Performance

According to [40], performance is a showcase of a person's understanding, conceptions, skills, thoughts, and expertise. Academic performance should be controlled properly, keeping in mind aspects that can negatively or positively affect it [3]. Academic performance refers to a numeric value of a student's knowledge that shows the level of her/his adaptability to the learning system. In [40], it was stated that students and teachers benefit from the internet to improve their academic performance in terms of achievement and teaching, respectively. In general, all definitions of performance refer to expressing capabilities and achieving a goal. In this work, we use the GPA of the students, according to Table 2, to measure their academic performance, as employed in several studies [31,41].

Table 2. Operationalization of academic performance variable.

Variable Definition Stage	Content
Concept	Academic performance.
Dimensions	Academic performance in each of the subjects approved by the student.
Indicators	Grade obtained out of 10 points in each of the subjects approved by the student.
Index: GPA	Weighted average of the grades of the subjects according to the credits of each one.

2.2. Source of the Data, Data Collection, and Field Work

We use original data generated by the authors of the present study and acquired from Uttarakhand undergraduate and postgraduate management students. Because we wish to apply our findings to a larger community in Uttarakhand, which is heterogeneous in terms of background, knowledge, and understanding, stratified random selection with proportional sample allocation is considered. Therefore, each university was divided into strata, and samples were gathered from each strata utilizing random sampling. Because each university has a varied number of students, we collected data employing proportionate allocation. As the overall population, that is, management students who use

smartphones, is roughly 800, we considered a sample size of $n = 252$ to $n = 278$ with a 10% and 5% margin of error, respectively, based on [42].

To meet our objective, data were collected through a survey of undergraduate and postgraduate management students from five distinct Dehradun institutions. This sample must reflect the appropriate demographic characteristic for our study. The questionnaire constructed for the present investigation has 43 questions that are clear, non-offensive, and simple to answer, in addition to including both closed-ended and open-ended questions. The instrument asked for responses related to demographic, academic, and technological factors. The data gathered are employed to compare the usage of WhatsApp among various age groups and programs. To ensure that the data collected are reliable and of high quality, we first briefed and taught the respondents about the survey, and then, we considered a pilot study on 30 students (17 postgraduates and 13 graduates).

The pilot survey took place from 12 March 2020 to 18 March 2020. The data were collected after applying the final questionnaire from 25 March 2020 to 10 April 2020. This was the timeframe of the lockdown at the national level in India, and pupils had plenty of time to read and deliver the necessary data. We distributed the questionnaire (by employing a Google form) to 340 students of whom 258 answered (response rate 75.8%), indicating that the survey is legitimate [43]. Correct usable responses were obtained and then utilized for the data analysis.

The variables to be used investigate five categories as follows: (i) personal: gender, age, academic year, GPA, school, and university demographic data; (ii) appropriation: factors or points that aid in WhatsApp adoption; (iii) incorporation: time spent per day on WhatsApp, why use WhatsApp, what features are employed, and types of data transferred; (iv) objectification: the value of WhatsApp; and (v) conversion: challenges and addiction factors.

2.3. Statistical Methods

In factor analysis—FA [44]—the original variables are written as a linear combination of the common and specific factors. Let X_j be original variable j, for $j \in \{1, \ldots, p\}$. Suppose f_k is common factor k, for $k \in \{1, \ldots, q\}$, and u_j is a specific factor j. Then, we have that

$$X_j = \lambda_{j1} f_1 + \lambda_{j2} f_2 + \cdots + \lambda_{jq} f_q + d_j u_j, \quad j \in \{1, \ldots, p\}. \tag{1}$$

The coefficients λ_{jk} and d_j, for $j \in \{1, \ldots, p\}$ and $k \in \{1, \ldots, q\}$, are known as loadings. In addition, we have the following model assumptions with orthogonal factors: (i) $\forall h \neq m$, $\mathrm{Cor}(f_h, f_m) = 0$; (ii) $\forall h \neq m$, $\mathrm{Cor}(u_h, u_m) = 0$; and (iii) $\forall h$ and $\forall m$, $\mathrm{Cor}(f_h, u_m) = 0$. Furthermore, all factors are assumed to be standardized.

Note that the expression given in (1) can be formulated in matrix form as

$$\boldsymbol{X} = \boldsymbol{F}\boldsymbol{\Lambda}^\top + \boldsymbol{E}, \tag{2}$$

where $\boldsymbol{X} = (x_{ij})$ is the data matrix of order $n \times p$, $\boldsymbol{F} = (f_{ik})$ is the score matrix of order $n \times q$, $\boldsymbol{\Lambda} = (\lambda_{jk})$ is the factor matrix of order $p \times q$, and $\boldsymbol{E} = (e_{ij})$ is the error matrix of order $n \times p$. In (1), $d_j u_j$ is considered as an error term, that is, $e_j = d_j u_j$. The FA has as its main goal to find and interpret the factor matrix $\boldsymbol{\Lambda}$ stated in (2). To achieve a dimension reduction, we need $q < p$. There are some algorithms to minimize the residual sum of squares represented as

$$\begin{aligned} &\min_{\boldsymbol{F},\boldsymbol{\Lambda}} \|\boldsymbol{E} = \boldsymbol{X} - \boldsymbol{F}\boldsymbol{\Lambda}^\top\|^2, \\ \text{subject to:} \quad &\boldsymbol{\Lambda}^\top\boldsymbol{\Lambda} = \boldsymbol{I}_q. \end{aligned}$$

Some of these algorithms are the maximum likelihood, least squares, and PCA methods. We use the SPSS software to compute the matrix $\boldsymbol{\Lambda}$.

Contrary to what happens in FA, in PCA, each component is written as a linear combination of the original variables. For a detailed discussion of PCA, see [44]. Let X_j be original variable j and c_l be component r $(r < p)$. Then, we get

$$c_l = b_{1l}X_1 + b_{2l}X_2 + \cdots + b_{pl}X_p, \quad l \in \{1, \ldots, r\}. \tag{3}$$

The coefficients b_{jl}, for $j \in \{1, \ldots, p\}$ and $l \in \{1, \ldots, r\}$, are known as loadings. Calculation of components formulated in (3) is conducted sequentially. For the first component, its variance is maximized. For the second one, its variance is maximized, and it must be orthogonal to the first component. For the third one, its variance is maximized, and it must be orthogonal to the two previous components, and so on. In general, the variance of each component is maximized, and the constraint that this new component must be orthogonal to all previous components is added. The model assumes that the components are unitary and independent. In matrix terms, the PCA is modeled by

$$\boldsymbol{X} = \boldsymbol{A}\boldsymbol{B}^\top + \boldsymbol{E}, \tag{4}$$

where $\boldsymbol{X} = (x_{ij})$ is the $n \times p$ data matrix, $\boldsymbol{A} = (a_{il})$ is the $n \times r$ score matrix containing the coordinates of the n individuals in the reduced dimension space, $\boldsymbol{B} = (b_{jl})$ is the $p \times r$ loading matrix, and $\boldsymbol{E} = (e_{ij})$ is the $n \times p$ error matrix. In PCA, we must calculate and interpret the matrix $\boldsymbol{B}$ stated in (4). There are some algorithms, based on the singular value decomposition of matrices, to solve the optimization problem formulated as

$$\begin{aligned} & \min_{\boldsymbol{A},\boldsymbol{B}} \|\boldsymbol{E} = \boldsymbol{X} - \boldsymbol{A}\boldsymbol{B}^\top\|^2, \\ \text{subject to:} \quad & \boldsymbol{B}^\top\boldsymbol{B} = \boldsymbol{I}_r. \end{aligned}$$

We employ the `R` software to calculate the components of the PCA.

Interpreting the matrix $\boldsymbol{B}$ means that we can unambiguously determine how the components group the original variables. If the matrix $\boldsymbol{B}$ is not interpretable, rotational techniques are utilized, keeping the fit of the data. However, current research suggests losing a bit of fit to gain interpretation, using the technique of disjoint principal component analysis (DPCA) [45,46]. When using disjoint components, each original variable belongs to just one component. Furthermore, each component must take at least one of the variables. This facilitates the interpretation of the matrix $\boldsymbol{B}$ and allows an easy characterization of the components. In [45], an alternate least squares algorithm for calculating disjoint components is stated. In [46], an algorithm is proposed, based on particle swarm optimization, to calculate disjoint components and can be applied to big matrices with good execution times. In this work, we utilize both algorithms obtaining the same results. In [38], an efficient text document clustering approach using a multi-search arithmetic optimization algorithm was introduced. From [47], we have the following definition.

Definition 1 (Disjoint matrix)**.** *Let $\boldsymbol{B} = (b_{jl})$ be a $p \times r$ matrix, where $p > r$. Then, $\boldsymbol{B}$ is disjoint if and only if, for any j, there exists only one l such that $b_{jl} \neq 0$, and for any l, there exists j such that $b_{jl} \neq 0$. If $\boldsymbol{B}$ also satisfies $\boldsymbol{B}^\top\boldsymbol{B} = \boldsymbol{I}_r$, where $\boldsymbol{I}_r$ is the $r \times r$ identity matrix; then, $\boldsymbol{B}$ is a disjoint orthogonal matrix.*

To compute disjoint components, the optimization problem expressed as

$$\begin{aligned} & \min_{\boldsymbol{A},\boldsymbol{B}} \|\boldsymbol{X} - \boldsymbol{A}\boldsymbol{B}^\top\|^2, \\ \text{subject to:} \quad & \boldsymbol{B}^\top\boldsymbol{B} = \boldsymbol{I}_r, \end{aligned}$$

with $\boldsymbol{B}$ being a disjoint matrix that must be solved. We can view an orthogonal disjoint matrix as a special type of a sparse matrix.

When disjoint components are used, each component is written as a linear combination of a subset of the original variables. The algorithm that computes the disjoint components decides which original variables disappear from the linear combination. From the expression given in (3) and without loss of generality, assume that the h-th component, with $l = h$, groups the k first original variables $X_1, \ldots, X_k$. Consider the linear combination

$$c_h = b_{1h}X_1 + b_{2h}X_2 + \cdots + b_{kh}X_k + b_{(k+1)h}X_{k+1} + \cdots + b_{ph}X_p. \quad (5)$$

Note that in the equation given in (5), the last $p - k$ scalars are equal to zero, that is, $b_{(k+1)h} = \cdots = b_{ph} = 0$. Thus, the component c_h is a linear combination of the original variables $X_1, \ldots, X_k$. This facilitates the interpretation of the loading matrix $\boldsymbol{B}$ and, therefore, the characterization of the r principal components.

3. Case Study

In this section, we apply the methodology presented in Section 2 to the WhatsApp Indian data. We summarize the methodology proposed for dimension reduction stated in Section 2.3 in an algorithm.

3.1. Algorithm and Computer Settings

In our study, the calculations were carried out on a computer with Windows 10 for 64 bits, 8 Gigabytes of RAM and processor Intel Core i7-4510U 2-2.60 GHZ. Regarding the software, we used `R` and `SPSS`.

Algorithm 1 and Figure 1 provide a summary of the methodology proposed for the dimension reduction, where we utilize rotation methods and disjoint components (a special type of the sparse technique). To compute the disjoint components, the algorithms proposed in [45,46] were implemented. In the computational experiments conducted in this work, each algorithm was executed five times and the best solution was considered, which was obtained in eight seconds and three iterations during the processing.

Algorithm 1 Method for dimension reduction.

1: Collect the data in a matrix $\boldsymbol{X}$ of order $n \times p$, where n is the number of individuals and p is the number of variables.
2: Standardize $\boldsymbol{X}$ subtracting the mean and dividing by the standard deviation of each variable.
3: Apply an FA determining the number q of factors ($q < p$) to be extracted from $\boldsymbol{X}$ using some known method (for example, the scree test).
4: Compute q factors from $\boldsymbol{X}$, fit the model with some known extraction method (for example, PCA), and go to Step 7 if the factor matrix $\boldsymbol{F}$ is interpretable; otherwise, continue with Step 5.
5: Use rotation methods (data fit is kept) and go to Step 7 if the factor matrix $\boldsymbol{F}$ is interpretable; otherwise, continue with Step 6.
6: Employ a DPCA computing q disjoint components from $\boldsymbol{X}$ and fit the model based on the algorithms proposed in [45,46].
7: Plot the reduced space of the variables.
8: Interpret the latent dimensions and conclude.

The methodology we propose seeks to facilitate the task of the data scientist. When performing a dimension reduction analysis, the most important objective is to interpret and characterize the latent dimensions. The first attempt is to carry out an FA using PCA to compute the latent dimensions (in general, any extraction method can be used).

If the factorial matrix $\boldsymbol{F}$ is not interpretable, we recommend to apply some rotation method to obtain an interpretable factorial matrix $\boldsymbol{F}$, maintaining the fit of the model. If the non-interpretation problem persists, we suggest calculating disjoint components, losing a bit of fit in the model. We can see this procedure as a flow diagram in Figure 1. Computing disjoint components has the consequence of losing a bit of fit in the model,

but the interpretation of the latent dimensions is guaranteed. The advantage of disjoint components can be seen in tables and figures presented in the next subsections.

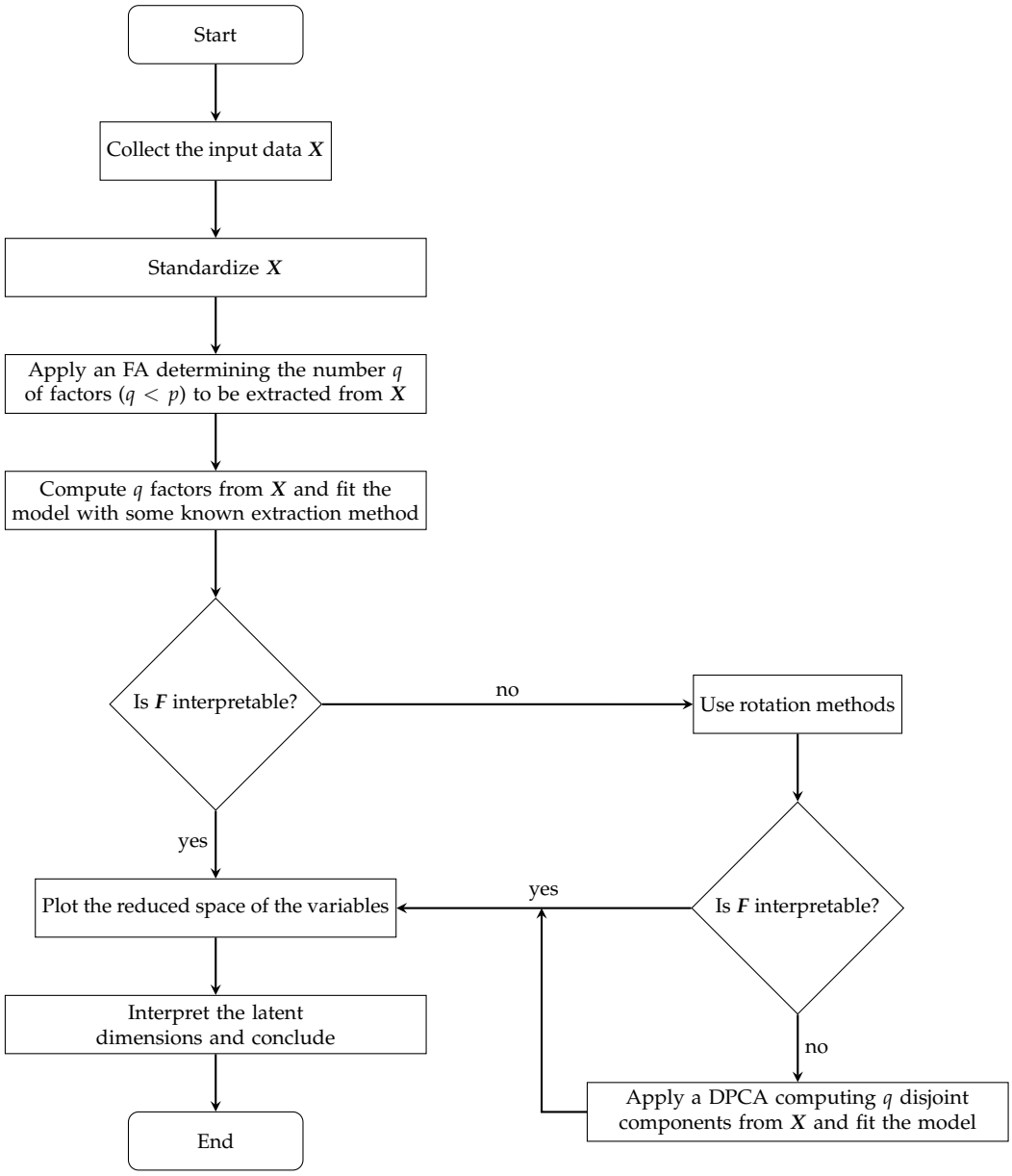

Figure 1. Flow diagram of the methodology for dimension reduction.

3.2. Exploratory Data Analysis

We employ descriptive statistics to show demographic data and trends in this study. The use of WhatsApp and its relation with academic achievement were assessed utilizing a 14-item instrument. A 5-point Likert scale was employed to collect the responses from the students; see Table 3. Furthermore, the 14 items related to addiction were subjected to an FA for determining the instrument's dimensionality and variables that could be utilized for addiction representation. The association between WhatsApp use and academic achievement was investigated based on Spearman correlations between variables.

In the present study, 258 students responded; the majority of them are male (58.9%) and the remaining 41.1% are female from first (85.7%), second (12.0%) and third (6%) year courses. Figure 2 shows the distribution of population by background characteristics. Among the 258 students under analysis, 109 are bachelor of business and administration (BBA) students and 149 are master of business and administration (MBA) students. The

respondent's age range is 18 to 28 years, with the age groups: (i) 18–20 years old (46.9%); (ii) 21–23 years old (39.1%); (iii) 24–26 years old (12%); and (iv) 26–28 years old (1.9%). Respondents were drawn from four universities in Uttarakhand, India. Most of the students come from UPES (60.1%), IMS (36.7%), DIT (1.6%), and Graphic Era University (1.6%). Thus, because the replies from UPES are in the majority when compared to other universities, we did not divide the responses by university to avoid any bias. Out of the total number of respondents, 143 (55.4%) live off campus and 115 (44.6%) live in a dormitory on campus, away from their home; see Table 4.

Table 3. WhatsApp items studied in the dimension reduction.

Item	Question
I.1	I frequently find myself utilizing WhatsApp for longer periods of time than I expect.
I.2	Without WhatsApp, I often find life to be tedious.
I.3	Because of my WhatsApp usage, I frequently neglect my schoolwork.
I.4	When someone stops me while I am on WhatsApp, I become upset.
I.5	It could be several days before I feel the need to utilize WhatsApp.
I.6	When I am on WhatsApp, time flies by and I do not notice it.
I.7	It is difficult for me to fall asleep after using WhatsApp.
I.8	I would be irritated if I had to limit the amount of time I spend on WhatsApp.
I.9	My family frequently complains about my WhatsApp obsession.
I.10	My school grades have suffered as a result of my use of WhatsApp.
I.11	While driving, I frequently use WhatsApp.
I.12	Because of my work with WhatsApp, I frequently cancel plans with pals.
I.13	When I have not used WhatsApp, I find myself worrying about what happened there.
I.14	Since I started using WhatsApp, I believe my utilization has increased dramatically.

Table 4. Demographic information of samples by sex.

Variables	Male		Female		Total	
	n	%	*n*	%	*N*	%
Age group						
18–20	77	50.7	43	40.6	120	46.5
21–23	50	32.9	51	48.1	101	39.1
24–26	21	13.8	9	8.5	30	11.6
26+	4	2.6	3	2.8	7	2.7
GPA						
Less than 4	2	1.3	1	0.9	3	1.2
4 and above but below 6	13	8.6	7	6.6	20	7.8
6 and above but below 8	97	63.8	54	50.9	151	58.5
8 and above	40	26.3	44	41.5	84	32.6
Program						
BBA	69	45.4	40	37.7	109	42.2
MBA	83	54.6	66	62.3	149	57.8
Academic year						
1st	133	87.5	89	84	222	86
2nd	16	10.5	13	12.3	29	11.2
3rd	3	2	4	3.8	7	2.7
On/off campus						
On campus	63	41.4	52	49.1	115	44.6
Off campus	89	58.6	54	50.9	143	55.4

Regarding appropriation, according to the study's findings, 218 out of 258 students (84.7%) reported using WhatsApp during academic pursuits (such as during classes). Most students (198) employed WhatsApp to communicate with their teachers for academic purposes. Among the 258 respondents, 97 have joined three to four academic groups, 96 have joined one to two groups, 46 have joined more than five groups, and 19 have joined

none. On a five-point Likert scale, the influence of WhatsApp employment on students during academic activities is assessed. Many respondents (72) indicated that utilizing WhatsApp interferes with their studies just occasionally, while 82 say it sometimes helps them to learn, and 43 claim it happens all the time. However, 80 respondents believe that messages received on WhatsApp occasionally affect their ability to focus, while 25 believe it happens all the time. In addition, 51 stated they never respond to WhatsApp messages received during class, 78 said they seldom respond, and 30 said they often respond.

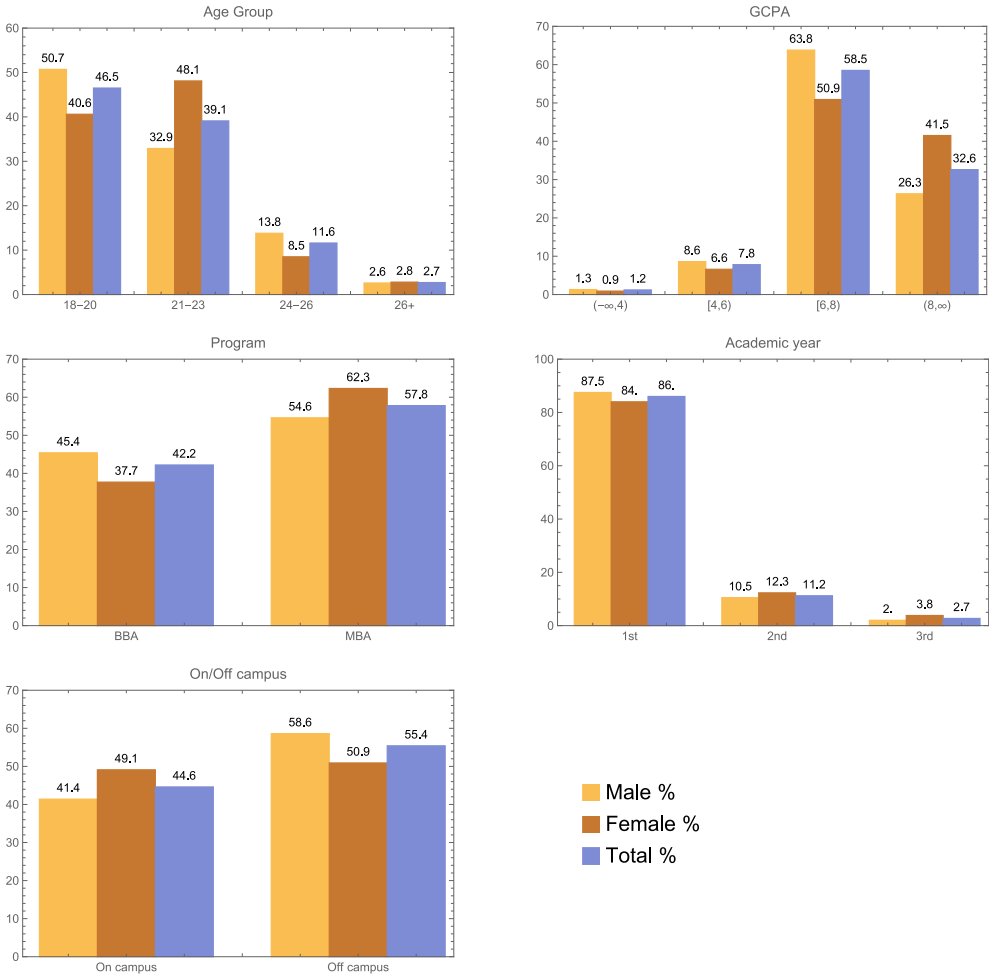

Figure 2. Distribution of population by the indicated background characteristic.

In relation to incorporation, most of the respondents (200) had been using WhatsApp for more than two years, according to the survey. Many respondents (140) spent less than two hours each day employing WhatsApp, whereas 86 spent three to five hours per day. Sending text messages (41.5%), sending photographs (29.1%), sending videos (15.9%), sending news, events, etc. (10.1%), and sending voice messages are the current WhatsApp services that students utilize. Pupils were questioned why they use WhatsApp so frequently to gather information on the causes for their frequent utilization. According to the findings, most students (187) admitted to employing WhatsApp since it is simple to interact with and there are no additional costs.

The students' data-sharing behavior, specifically whether they tend to forward or disseminate material relevant to news, events, advertisements, or any study-related matters to others, is an aspect to emphasize in this study. According to our findings, most students (130) only do so to share information if they believe it is valuable, relevant, or true. This hypothesis was followed by 49 respondents who stated that they do not disseminate the material at all. They did not wish to freely transfer message or media contents for a variety of reasons, including a lack of interest in disseminating, privacy concerns, and,

most critically, apprehension about sharing material that might be unregulated or from an untrustworthy source. The findings of this survey also revealed that many students (113) solely communicated information pertaining to their study topics.

Regarding objectification, when students were asked how they saw or valued the WhatsApp messaging service, the overall results revealed that most of them agreed that WhatsApp is just a "regular communication application" rather than something to which they would be more attached, such as their "life" or "best friend". Considering the study's findings, 138 persons stated they check WhatsApp during their leisure time, and 63 claimed they use it constantly since it is a vital part of their lives.

With respect to conversion, according to this study, 144 students said they would continue to employ WhatsApp even if it was no longer free, and 171 said they would continue to use it in the next two years. This research also revealed the kind of issues that students had when utilizing WhatsApp. Most of them (83) realized that using WhatsApp increases others' expectations, or that they must respond to messages instantly, whereas 84 gave a neutral response. Other issues raised from the study included the possibility that utilizing WhatsApp could lead to addictive-like behavior, such as the inability to stop chatting, reacting, and exchanging data. Furthermore, 43 of the students established that WhatsApp interferes with their studies. Surprisingly, many of the respondents agreed that employing WhatsApp interfered with their social responsibilities, while 59% said that it affected their physical activity.

3.3. Confirmatory Analysis: Dimension Reduction, Results and Discussion

The purpose of this study is to examine the relationship between the use of WhatsApp and academic performance in management students. For this, an FA was applied using PCA as extraction method, with varimax rotation on the 14 validated items; see Table 3.

The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy indicated that we should be confident that the FA is appropriate for considering and theory building. The value of KMO $= 0.824$ is greater than the recommended value of 0.5, while the Bartlett test of sphericity is also significant with $\chi^2 = 1183.327$ and p-value < 0.001 [48]. In addition, the sample size $n = 258$ is more than 10 times the number of variables, which is equal to 14 [49]. All these results suggest that the FA is appropriate and good to draw conclusions. All the items are standardized to ensure proper interpretation on a common scale. Scree plot and eigenvalues are examined to extract the appropriate number of factors; see Figure 3.

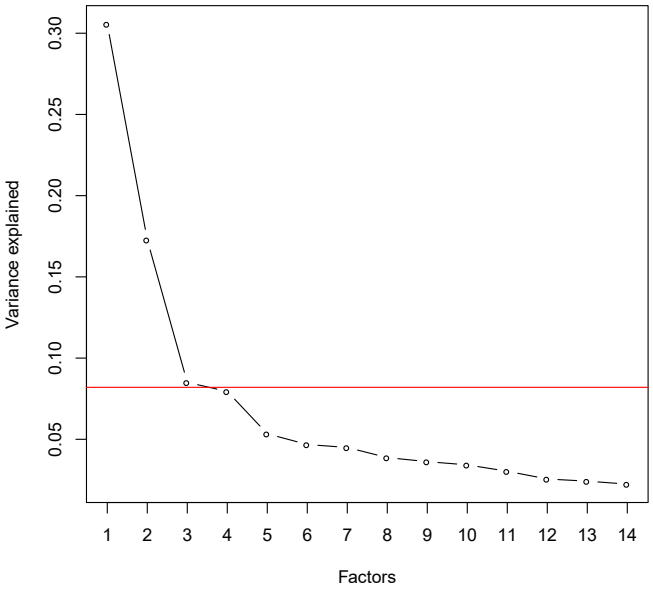

Figure 3. Variance explained by each factor for WhatsApp Indian data.

The 14 WhatsApp addiction items considered in this study are grouped into three factors based on the responses from students. Thus, factor 1 (FACT1 = addicted) includes deteriorated grades, usage of WhatsApp while driving, canceling meeting of friends, and worry about WhatsApp if I do not use it. Factor 2 (FACT2 = socially isolated) considers long time use, life is tedious without WhatsApp, and feeling upset if someone stops me from using WhatsApp. Factor 3 (FACT4 = time pass) includes time flies, feeling irritable, and my utilization has increased. Table 5 shows the factor matrix after applying a varimax rotation. We can see that the items have a strong representation on only one factor, except for items 9, 10, 11 and 14. The three factors capture 56.35% of data variability. Figure 4 shows the reduced dimension space for the 14 WhatsApp items.

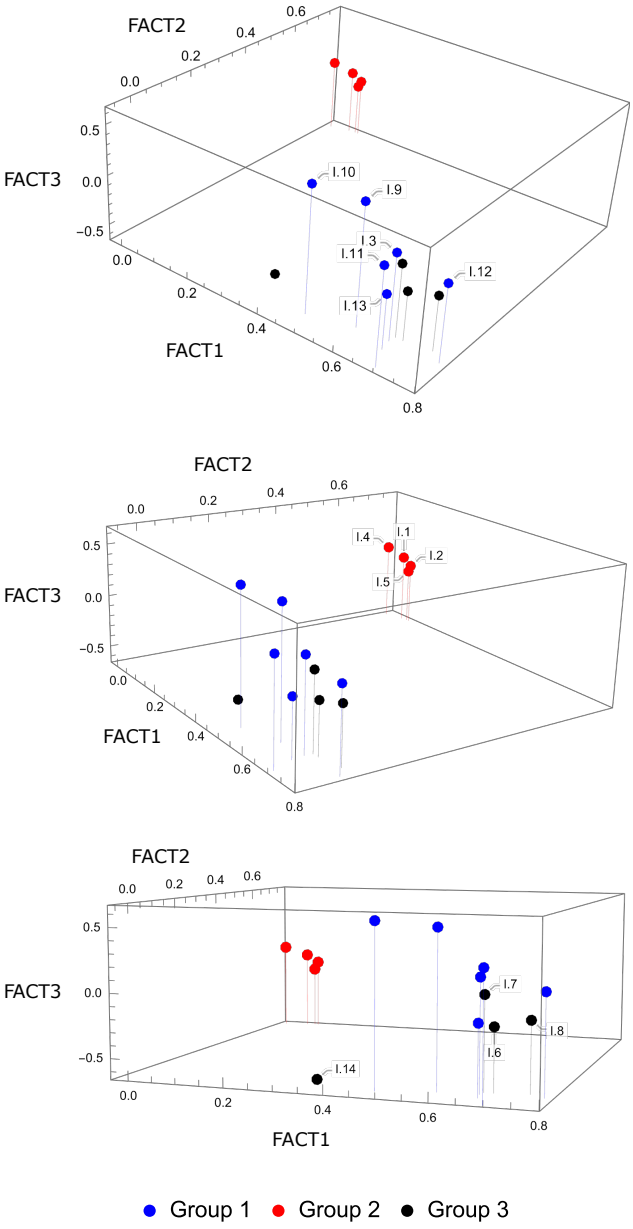

Figure 4. WhatsApp items space on three factors for Indian data in three different perspectives.

The association of these factors with use of WhatsApp is examined by analyzing the Spearman correlation between students GPA, time spent on WhatsApp, hours that students sleep, use of app during class time, assistance of app in learning, disruption of app on the study. The results show that there is no significant relation between the GPA and factors:

FACT1, FACT2, and FACT3. The findings from this study show a positive correlation between times spent on WhatsApp and academic performance measured by the GPA of the students, which is similar to the investigation presented in [25]. In addition, hours of sleep is not related to GPA.

From Table 6, note that the time spent on WhatsApp is disruptive to study with both being positively correlated to the factors FACT1, FACT2, and FACT3. It means there is more addiction toward WhatsApp and time spent on WhatsApp by students. From Table 4, it is evident that answering on WhatsApp during class is significantly associated with assistance of WhatsApp in learning, but more use of this app in class is negatively correlated with GPA. Hence, the study concludes that student's performance in GPA has no relationship with use of WhatsApp, but sometimes, this app assists students in their learning and performance.

Table 5. Factor matrix with varimax rotation for WhatsApp Indian data.

Item	FACT1	FACT2	FACT3
I.1	0.03034481	0.77696482	0.01330276
I.2	0.05754937	0.78045361	−0.05502791
I.3	0.66457462	0.03210919	0.19216345
I.4	−0.02081977	0.76241137	0.08598149
I.5	0.04886396	0.78056599	−0.12410521
I.6	0.68613833	0.05302230	−0.17519906
I.7	0.66773043	0.05226233	0.05748970
I.8	0.75232506	0.06495718	−0.12037056
I.9	0.58525987	0.02516156	0.54438397
I.10	0.47527431	−0.00832741	0.58734625
I.11	0.69459116	−0.06134892	0.29867599
I.12	0.78418094	0.03884651	0.10346175
I.13	0.67026382	−0.00221434	−0.12314120
I.14	0.33133921	0.06890374	−0.66348807
% of variance	30.56%	17.28%	8.51%

Table 6. Spearman correlation between the variables (correlation matrix) with WhatsApp Indian data.

	GPA	Time Spent on WhatsApp	Hour You Sleep	App Is Disruptive to My Study	Do You Answer during Class on App	Assistance of App on Learning	FACT1	FACT2	FACT3
GPA	1								
Time spent on WhatsApp	0.198 *	1							
Hours you sleep	−0.083	−0.049	1						
App is disruptive to my study	−0.024	0.048	−0.104	1					
Do you answer during class on app	−0.062	0.098	0.013	0.111	1				
Assistance of app on learning	0.018	0.099	0.029	0.054	0.308 *	1			
FACT1	0.08	0.063	−0.042	0.06	0.053	−0.117	1		
FACT2	−0.014	0.006	0.087	0.136	0.118	0.029	0.477 **	1	
FACT3	−0.057	0.024	−0.026	0.037	−0.026	0.016	0.036	0.104	1

* Correlation is significant at 5% (two-tailed). ** Correlation is significant at 1% (two-tailed).

The GPA of students and connections with teachers on WhatsApp is detected by the chi-square test as well as the relationship with the use of WhatsApp in academic activities. According to our findings, there is a substantial relation between students' use of WhatsApp during academic activities and their connections with teachers on the app. However, there is no relation between GPA and WhatsApp utilization through academic activities, which is in accordance with the work presented in [27,28]. Table 7 illustrates the crosstabulated findings of using WhatsApp for academic purposes with a variety of variables.

Table 7. Crosstabulated results of WhatsApp usage during academic activity with several variables of the Indian data.

Variables	*p*-Value	Result
Age group	0.162	Non-significant
Program	0.161	Non-significant
Academic year	0.341	Non-significant
GPA	0.014	Significant
How many academic groups you have joined?	<0.001	Significant
Are you connected with your teachers over WhatsApp?	0.003	Significant
How long you have been using WhatsApp?	0.008	Significant
How many hours do you normally spend using WhatsApp?	0.735	Non-significant

To compare with FA and improve data interpretation, a DPCA was also carried out using three components. In Table 8, we can see the loading matrix that was obtained with classical components. The last row shows the percentage of variance captured by each component. In total, the three components capture 56.35% of the variability of the data. The disjoint components help us to improve the interpretation of the loading matrix.

When computing disjoint components, Table 9 reports the loading matrix. Now, the three components capture 54.95% of the data variability. Therefore, we lose 1.4% of the information, but we gain in data interpretation. Figure 5 shows the reduced dimension space for the 14 WhatsApp items with disjoint components.

We conclude that items #3 and #9–13 are grouped in component 1 (COMP1), that component 2 (COMP2) catches items #1, #2, #4, and #5, and that, then, items #6, #7, #8, and #14 are represented by component 3 (COMP3). By comparing Tables 5 and 9, we can say that COMP1 is FACT1, COMP2 is FACT2, and COMP3 is FACT3.

Note that COMP1 represents a high dependency on WhatsApp. Two items that we could incorporate for future studies, to further support this conclusion, could be: "During lunch or dinner, I frequently use WhatsApp" and "While watching TV, I frequently use WhatsApp".

Observe that COMP2 states the isolation to which a person is subjected by the use of WhatsApp. Items that can be added in the future that are aligned with this component could be "If I am in a meeting with family or friends, I use WhatsApp a lot" and "When I am on a date, I use WhatsApp a lot".

We note that COMP3 indicates a growing use of WhatsApp; that is, as the days go by, the percentage of daily use of WhatsApp increases. To support this conclusion, we could in the future consider for example adding these two items: "I have stopped doing some activities since using WhatsApp" and "I see less and less of my family or friends since using WhatsApp". All feedback obtained allows us to improve the instrument for future research.

In [50], we can see another data analysis using DPCA with COVID-19 data. In [47,51], we identify alternating least squares algorithms to compute disjoint components in three-way tables.

In Table 10, we report a summary of the dimensional reduction analysis. The three latent dimensions have been clearly characterized. The methodology that we propose in Algorithm 1, based on the use of disjoint components and component rotation techniques, was employed to obtain these conclusions. Furthermore, in Figure 5, we observe the WhatsApp items clearly grouped. The results have provided with important feedback that will allow us to improve the measurement instrument in future studies.

Table 8. Loading matrix of the PCA with WhatsApp Indian data.

Item	COMP1	COMP2	COMP3
I.1	0.06120081	0.48800513	−0.10260894
I.2	0.06868628	0.49530998	−0.03746529
I.3	0.33181342	−0.03971009	−0.06273129
I.4	0.04209015	0.47475063	−0.17432843
I.5	0.05894249	0.50276602	0.02267637
I.6	0.31322646	0.00861019	0.26609010
I.7	0.32348943	−0.01380947	0.05546726
I.8	0.34970328	0.00663979	0.22692268
I.9	0.32268022	−0.07414106	−0.38955820
I.10	0.27221475	−0.09279499	−0.44240153
I.11	0.34920303	−0.11120559	−0.14113490
I.12	0.38151494	−0.03402578	0.03585147
I.13	0.30672033	−0.03049404	0.22377153
I.14	0.10651257	0.08893395	0.63960978
% of variance	30.56%	17.28%	8.51%

Table 9. Loading matrix of the DPCA with WhatsApp Indian data.

	COMP1	COMP2	COMP3
I.1	0	0.49991922	0
I.2	0	0.50600674	0
I.3	0.38329163	0	0
I.4	0	0.48623616	0
I.5	0	0.50755527	0
I.6	0	0	0.53927580
I.7	0	0	0.55485563
I.8	0	0	0.60386256
I.9	0.39677193	0	0
I.10	0.38052728	0	0
I.11	0.45834493	0	0
I.12	0.45175363	0	0
I.13	0.36972576	0	0
I.14	0	0	0.19148591
% of variance	22.67%	17.22%	15.06%

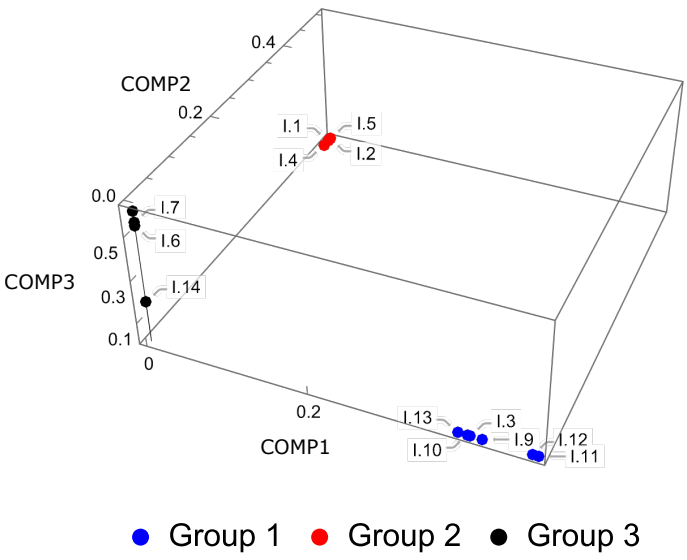

Figure 5. WhatsApp items space on three disjoint components for Indian data.

Table 10. Summary of dimensional reduction analysis.

Latent Dimension	Characterization	Grouped Items
FACT1/COMP1	Addicted: High dependency on WhatsApp	I.3, I.9, I.10, I.11, I.12, I.13
FACT2/COMP2	Socially isolated: Isolation due to the use of WhatsApp	I.1, I.2, I.4, I.5
FACT3/COMP3	Time pass: Growing use of WhatsApp	I.6, I.7, I.8, I.14

4. Conclusions, Limitations and Future Research

In this section, we provide the conclusions of our investigation, some limitations of this, and ideas about future research.

4.1. Conclusions

This research established that there is no constructive relation between academic performance and use of WhatsApp by students. However, some past research showed that there is a positive association between academic performance and use of WhatsApp, indicating 57% students used WhatsApp for academic purposes. In [52,53], 56% students of Maharshi Dayanand University, Haryana, India opined that WhatsApp is beneficial for academic purpose. Thus, service providers can inculcate some features related to academic utilization to make it more effective. We have a big upcoming potential through digital platforms.

Students employ WhatsApp to disseminate their notes, and they remain in regular touch with their classmates. Hence, WhatsApp service providers should ensure an easy and smooth transfer of notes documents.

The majority of students spend less than two hours on WhatsApp, and they use it because it is easy, smooth and free to utilize. Mostly students share valuable, relevant information through the app. Then, all stakeholders should add some features for the easy dissemination of data. A similar study on WhatsApp has recently become popular as a result of its features, which include the ability to send real-time messages to an individual or group of friends at the same time as well as its low cost and privacy [54].

The purpose of the present investigation was to determine the prevalence of WhatsApp usage among Dehradun bachelor and master management students. Factor and disjoint principal component analyses were carried out as part of the multivariate study applied to the WhatsApp Indian data generated for the present work. WhatsApp is simple to employ and communicate with for students. According to our findings, most students employ WhatsApp for academic purposes. WhatsApp's accessibility had no bearing on management students' academic achievement. Students said they utilized WhatsApp for less than two hours per day. According to the findings of our survey, many students exclusively disseminated materials pertaining to their academic topics through the app, which contribute to the easy dissemination of notes. Based on the findings, answering questions on WhatsApp during class is strongly associated with app learning assistance. Nevertheless, more app utilization in class is inversely correlated with the grade point average, which is similar to the study conducted on medicine students in [55]. Such a survey indicated that there is a negative impact on the employment of social media on academic performance. The survey concluded that while students' grade point average has no relationship with the use of WhatsApp, the app can sometimes assist students in their learning and performance. Training for the constructive usage of WhatsApp should be inculcated in the curriculum, which is supported by the investigation carried out in [55]. Additionally, there is a significant relation between students' utilization of WhatsApp during academic activity and the use of WhatsApp to communicate with lecturers. It also provides opportunities to share videos, pictures, class notes, and other academic materials, as also indicated by other authors [52].

4.2. Limitations and Future Research

Like all investigation, this is also has some limitations. Firstly, our sample focuses on a single demographic area, that is, Dehradun, which can be used as a basis for further research in other demographic setups. Secondly, this investigation was stated to know the effects of WhatsApp on academic performance of management students, which is a limitation. Thirdly, many other variables such as socioeconomic status, residential area, daily hours devoted to study, accommodation, academic background, family background, and age, among others, which influence the academic performance of a students, can be explored. This is another limitation of this research and can be addressed in further works.

4.3. Future Research

We postulate the following recommendations to be considered:

(i) Extend this study on the effect of WhatsApp on academic performance to students of other disciplines and other countries.
(ii) Propose an information system for data warehouse compilation that allows different databases to coexist for acquiring necessary data from university records.
(iii) State a data-monitoring plan to track the performance of students for further analysis and decision making.
(iv) Formulate a model for predicting students at risk of dropout due to an excessive use of WhatsApp.
(v) Schedule a plan for at-risk students who are identified by the predictive model to assist them in improving academic results.
(vi) Consider other variables that may have an impact on students' academic performance, for example, variables related to social media (such as the use of Facebook and Instagram) or not (as social economic status, residential area of students, daily study hour and accommodation).

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