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Using the Canonical Correlation Analysis Method to Study Students' Levels in Face-to-Face and Online Education in Jordan

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Abstract: The study aims to identify the existing correlations between the two sets of variables by finding the linear combinations of the two sets of variables with the highest correlation and test the strength of the relationship between the levels of students' face-to-face education and online business students at Al-Balqa Applied University by using the canonical correlation test, The study was applied to a sample of students from Al-Balqa Applied University, specifically the faculty of Business, and for the purposes of analysis and extraction of results, (SPSS ver.26), and (Stata graphics ver.11) programs were used. The study reached the following results the first, second, and third Canonical correlations are statistically significant at the level of significance ($\alpha \leq 0.05$), and the first, second, and third canonical correlation between canonical variables independents and dependents is equal (0.98, 0.965, 0.907) respectively, and the variance explained between independent and dependent canonical variable is equal (93.24%, 4.7%, 2.047%) for first, second, and third Canonical correlations respectively. The study recommends using the canonical correlation to evaluate Jordan's experience in online education in schools and universities.

Keywords: Canonical correlation,face-to-face, online education, Al-Balqa Applied University.

1 Introduction

The canonical correlation is one of the methods of multivariate analysis and a statistical method used to measure and determine the correlation between two groups of the study. The scientist Hotelling was the first to refer directly to the orthodox correlation and that was in the year 1936 [1], and in the year (1985) the general formula for the analysis of the orthogonal correlation was put forward by Gittens, as for the parameters of functions for analyzing the canonical correlation in the case of discontinuous and continuous data, they were discussed by Bockenholt in the year 1990, as well as by YanaiTakane in the year 1992 , as discussed in the general form of the orthodox correlation analysis by both Basilevsky in the year 1994 and Gnanadesikan in the year 1997, also means the canonical correlation with the relationship between the linear combination of variables in one group and the linear combination of variables in another group, and the main idea in this lies in determining a pair of linear combinations that have the greatest correlation, followed by the combination of a pair of linear combinations that have the greatest correlation among all pairs incorrelated with the pair that was initially identified and so on, pairs of linear combinations are called canonical variables. Those correlations that measure the strength of the relationship between two sets of variables are called canonical correlations, and the most important aspect is focusing on the strong relationship between two sets of variables in several pairs of canonical variables.

Education is an important element of people's lives; based on their jobs, it can make or break them. Education is more diverse today than it was in the 1950s due to advancements in teaching methods and other notable inventions that apply more obvious teaching strategies. Once people speak about education, we frequently bring up online schooling. Students can thereby acquire skills and knowledge without leaving their homes [2]. Because the advancement of new technology such as the internet, students can now access learning from any part of the world. Almost all students have

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continuous access to the online education systems. Online learning is one of the most anticipated advancements in the global education market [3,4,5,6,7,8]. This kind of instruction is delivered via the internet. This technique of learning has been simplified by sophisticated and upgraded technologies [9,10,11]. Higher education institutions choose online education as well. The utilization of technological applications and learning processes is referred to as online education. Important links, such as internet connections, laptops, smartphones, and so on, are required for online education [12,13]. An electronic method of learning and teaching is included in online education. Online education occurs outside of the classroom on digital media. Lessons, animation, music, video, and graphics can all be used to deliver online education [14,15,16].

The research aims to identifying the existing correlations between the two sets of variables by finding the linear combinations of the two sets of variables with the highest correlation. And test the strength of the relationship between the levels of students' face-to-face education and online business students at Al-Balqa Applied University by using the canonical correlation test for the same subjects and comparing the test results.

2 The theoretical side

The canonical correlation is used to find the linear function of one group of variables that is highly correlated with the linear function of the other group of variables, and most often one of the two groups contains independent variables, while the other group contains dependent variables, as the correct correlation is a way to predict the multiple dependent variables through the variables' Multiple independents.

Assuming that we have two sets of variables (X) and (Y), and the first set (P) of variables represents the random vector (X) with a dimension (*px1*), the second set (q) of variables represents the random vector (Y) with dimension (*px1*), and that for each set (*n*) of sample points (*nxp*) a data matrix, and that both (X) and (Y) are vectors and that the population mean-variance, and covariance of the random variables (X) and (Y) can be expressed as follows [17,18]:

$$E(\underline{X}) = \mu_x \text{ , } E\left(\underline{y}\right) = \mu_y \text{ , } Cov(\underline{X}) = \sum xx \text{ , } Cov\left(\underline{y}\right) = \sum yy$$

$$Cov\left(\underline{X},\underline{y}\right) = \sum xy \sum yx$$

It is possible to express the matrix ($X^t.Y$) in segmented form as follows:

$$X^t.\text{Y}=\begin{bmatrix} X^t \\ \dots. \\ Y^t \end{bmatrix}.[X \quad \vdots \quad Y]=\begin{bmatrix} X^t.X & \vdots & X^t.Y \\ \cdots & \vdots & \cdots \\ Y^t.X & \vdots & Y^t.Y \end{bmatrix}$$

Such that: $Y^t.X= [X^t.Y]^t$ is a symmetric matrix with rank (*qxp*)

Assuming that (U) and (V) are linear combinations that can be calculated by:

$$U = a^t.\underline{X}V = b^t.\underline{Y}$$

Where (a), (b) the vector coefficients (*px1*), (*qx1*) for the linear combinations, and that the correlation between each pair of linear combinations (U) and (V) is of maximum value, and accordingly [19]:

$$maxCorrelation(U,V) = \rho^*{}_1 \qquad (1)$$

such that:

$$E(U) = zero \text{ , } E(V) = zero$$

$$V(U) = a^t Cov(\underline{X})a = a^t \sum XX\, a \qquad (2)$$

$$V(V) = b^t Cov(\underline{Y})b = b^t \sum YY\, b$$

$$COV(U,V) = a^t Cov(\underline{X},\underline{Y})b = a^t \sum XY\, b \qquad (3)$$

The correlation coefficient between (U) and (V) is called the canonical correlation, which can be calculated as follows:

$$Correlation(U,V) = \frac{a^t \sum XY\, b}{\sqrt{(a^t \sum XX\, a\,)(b^t \sum YY\, b\,)}} \qquad (4)$$

3 Derive the weights for each linear group

To derive a model, we consider a segmented vector from the elements (*p*) and (*q*) from the random variables [20,21,22]:

$$X = (\underline{X}.\underline{Y})^t = (\underline{X}_1\ \underline{X}_2\ \underline{X}_3\ \ldots\ \underline{X}_p\ \vdots\ \underline{Y}_1\ \underline{Y}_2\ \underline{Y}_3\ \ldots\ \underline{Y}_q)^t$$

$$\text{Var Cov (Matrix)} == \begin{bmatrix} \sum XX & \vdots & \sum XY \\ \cdots & \vdots & \cdots \\ \sum YX & \vdots & \sum YY \end{bmatrix}$$

Linear structure in the first group:

$$U = a_1\underline{X}_1 + a_2\underline{X}_2 + a_3\underline{X}_3 + \cdots a_p\underline{X}_p = a^t\underline{X} \quad (5)$$

Linear structure in the second group:

$$V = b_1\underline{Y}_1 + b_2Y_2 + b_3\underline{Y}_3 + \cdots b_q\underline{Y}_q = b^t\underline{Y} \quad (6)$$

That (X) and (Y) represent the standard values of the variables in the first and second groups, and that the correlation between the first group of the linear combination is called the first canonical correlation, which corresponds to the largest characteristic root, and that the correlation between the second set of the linear combination is called the second canonical correlation, which corresponds to the largest root special... and so on.

The correlation between the two linear structures is increasing, and in the issue of maximization and for the purpose of finding the canonical correlation, we assume that (Σ) represents the fragmented covariance and covariance matrix (*pxq*), and the coefficients that increase the correlation between the linear components ($U= a^tX$), ($V= b^tY$) is given by homogeneous linear equations where the coefficients of the canonical variables can be derived from the eigenvectors [23,24,25]:

$$(\Sigma^{-1}XX \sum XY\, \Sigma^{-1}YY \sum YX \text{ -}\lambda^2)a = zero \quad (7)$$

$$(\Sigma^{-1}YY \sum YX\, \Sigma^{-1}XX \sum XY \text{ -}\mu^2)b = zero \quad (8)$$

The Matrices ($\lambda = \mu = \alpha^t = \sum XY.b$) are the highest correlation and equations (7) and (8) are the normal equations for the canonical correlation analysis.

3.1 Canonical loadings

The canonical loadings coefficient is defined as a measure of the amount of the simple linear correlation coefficient between the original variables in one of the two sets of variables and their corresponding canonical variables, whose value ranges between (-1, +1) since squaring the canonical loadings coefficients, we get the amount of variations in the values of the original variables, which were explained by the canonical variables, also, the higher the load value, the more important the variable is in the linear combination. We can calculate the canonical loadings for the group (X) as follows [1,26,27]:

$$R_{u*X}(i) = R_{X*Xai} \quad (9)$$

R_{x*x}: Correlation matrix between independent group variables (X)

R_{u*x}: Canonical loadings for a group (X)

And calculate the canonical loadings for the group (Y) as follows:

$$R_{v*Y}(i) = R_{Y*Ybi} \quad (10)$$

R_{y*y}: Correlation matrix between independent group variables (Y)

R_{v*y}: Canonical loadings for a group (Y)

3.2 Redundancy Index

Characteristic values (λi) express the square of the canonical correlation coefficient between pairs of canonical variables. This value is known in the Canonical correlation analysis as the percentage of variance in the set of dependent variables (Yi) explained by the set of independent variables (Xi) or vice versa. This means that there is no difference between the independent and dependent variables, i.e., between cause and effect, and to avoid this problem. I propose a measure called the redundancy index. By this measure, the number of discrepancies in the values of the set of independent variables (Xi) or the values of the set of dependent variables (Yi) can be determined by any pair of canonical variables. The percentage of variations in the values of the set of dependent variables (Yi), which was explained by the canonical variable (i), can be determined as follows [26,28]:

$$R^2{}_{i(y)=\frac{1}{q}.R^t v*y(i)R_{v*y(i)}}$$

$$=\frac{1}{q}\sum_{j=1}^{q}[R_{v*y_j}(i)]^2 \quad (11)$$

Such that:

$R^2{}_{i(y):RedundancyIndexforthesetofvariables\ (Y)}$

$R_{u*v(i)}$: Canonical loadings

$R_{v*y_j}(i)$: Canonical loadings coefficient for the dependent variable no(j) in the Canonical variable no (i).

In the same way, we find the Percentage of discrepancies in the values of the set of dependent variables (Yi) that were explained by the canonical variable (i) as [29,30]:

$$R^2{}_{i(X)=\frac{1}{p}.R^t U*X(i)R_{u*X(i)}}$$

$$=\frac{1}{p}\sum_{i=1}^{p}[R_{u*X_i}(i)]^2 \quad (12)$$

Such that:

$R_{U*X(i)}$: Canonical loadings

$R_{U*X_I}(i)$: Canonical loadings coefficient for the independent variable no (i) in the Canonical variable no (i)

3.3 Canonical correlation coefficients test

All of the canonical correlations that we get from the analysis are statistically significant. Therefore, the significance of these correlations is tested in two stages, as follows:

(1) Test the null hypothesis which states that there is no significant correlation between the two groups. This hypothesis is formulated as follows [31,32]:

$$H_0: \sum yx = 0.0$$

$$H_1: \sum yx \neq 0.0$$

The previous hypothesis is equivalent to the following hypothesis [33]:

$$H_0: \rho^2{}_1 = \rho^2{}_2 = \cdots \rho^2{}_{p1} = 0.0$$

$$H_1: At\ least\ one\ not\ zero$$

If it is proven at this stage that there are moral differences, which means rejecting the null hypothesis, then transit to the second stage, but in the absence of moral differences, which means accepting the null hypothesis, then the test ends.

(2) Testing the significance of the greater canonical correlation in order to obtain the canonical variables, which are significant and sufficient to explain the relationship between two groups of variables.

Bartlett (1941) proposed a test for the statistical significance of the canonical correlations to test the independence between the two sets of random variables (X) and (Y), assuming that the two groups are not correlated, and they can be tested under natural assumptions with (Wilks) the statistical greatest possibility ratio, and the use of chi-square-statistics (χ^2) following [34,35,36]:

$$\chi^2 = -\left[(n-1) - \frac{1}{2}(p+q+1)\right] LnW \quad (13)$$

Such that:

W: Wilks Statistic

p: The number of variables in the first group

q: The number of variables in the second group

$$W = \frac{|(X^t.X)^{-1}X^t.Y(Y^t.Y)^{-1}Y^t.X|}{|X^t.Y|} \quad (14)$$

$$= \prod_{i=1}^{ri}(1-\lambda i^2) \quad (15)$$

Such that:

Canonical ri: The number of non-zero canonical correlation

λi^2: Correlation coefficient square

4 Application side

A random sample of (60) male and female students who were studying face to face in the classroom, and (60) male and female students who were studying online using the (Microsoft Teams) system, in addition, to (4) face-to-face, and on-line study courses online. The obtained data were analyzed to find out the strength of the relationship between the group of face-to-face studying course variables (X's), and the group of online study (y's)

Table 1: The Course name, group I (face-to-face education) and Group II (On-Line Education).

Course name	group I (face-to-face education)	Group II (On-Line Education)
Statistics	X_1	Y_1
Micro-Economics	X_2	Y_2
Macro-Economics	X_3	Y_3
Accounting	X_4	Y_4

A significant test of the relationship between the variables of the first group (X's), and the variables of the second group (Y's)

$H_0: \rho_1 = \rho_2 = zero$

$H_1: \rho_1 \neq \rho_2 \neq zero$

Table 2: The chi-square calculated, and chi-square tabulated for the first, second and third canonical correlation.

1st canonical correlation	$\chi^2 cal. = 245.78$	$\chi^2 tab._{(0.05,16)} = 26.296$
2nd canonical correlation	$\chi^2 cal. = 228.88$	$\chi^2 tab._{(0.05,16)} = 26.296$
3rd canonical correlation	$\chi^2 cal. = 95.93$	$\chi^2 tab._{(0.05,16)} = 26.296$

Notes that

$$\chi^2 cal. > \chi^2 tab._{(0.05,16)} \ whish\ means\ reject\ (H_0) and \text{ accept } (H_1)$$

Table 3: The canonical correlations, Eigenvalues, Wilks Statistic, and the significance of the canonical correlations.

	Correlation	Eigenvalue	Wilks Statistic	F	Num D. F	Denom D.F.	Sig.
1	.998	211.613	.011	219.229	16.000	159.500	.000
2	.956	10.670	.015	66.859	9.000	129.139	.000
3	.907	4.645	.172	38.142	4.000	108.000	.000
4	.174	.031	.970	1.719	1.000	55.000	.195

It is noted that the value of the first canonical correlation, the second Canonical correlation, and the third Canonical correlation are statistically significant at the level of significance ($\alpha \leq 0.05$), as the (P-Value) for each, is equal to (0.000), and the fourth right correlation is not significant at the level of significance ($\alpha \leq 0.05$), as the (P-Value), is greater than (0.05).

Table 4: The standardized canonical correlation coefficients for the first group (face-to-face study).

Variable	1	2	3	4
X1	.478	-2.532	1.229	-1.483
X2	.019	-.187	-.239	4.964
X3	.170	.013	-2.876	-3.526
X4	.356	2.717	1.826	.047

It is noted that the standardized canonical correlation coefficients, for the variables of the first group (face-to-face study) when the arithmetic mean, is equal to zero and the standard deviation is equal to (1).

Table 5: The standardized canonical correlation coefficients for the first group (face-to-face study).

Variable	1	2	3	4
Y1	.134	1.245	1.152	7.221
Y2	.188	1.350	.377	-7.426
Y3	.471	-2.338	1.201	-.104
Y4	.237	-.237	-2.771	.327

It is noted that the standardized canonical correlation coefficients, for the variables of the second group (online study) when the arithmetic mean, is zero equal to and the standard deviation is equal to (1)

Table 6: The unstandardized canonical correlation coefficients for the first group (face-to-face study).

Variable	1	2	3	4
X1	.060	-.321	.156	-.188
X2	.003	-.026	-.033	.685
X3	.026	.002	-.439	-.538
X4	.051	.387	.260	.007

It is noted that the unstandardized canonical correlation coefficients, for the variables of the first group (face-to-face study), when the arithmetic mean is not equal to zero and the standard deviation is not equal to (1)

Table 7: The unstandardized canonical correlation, coefficients for the second group (online study).

Variable	1	2	3	4
Y1	.019	.178	.165	1.035
Y2	.027	.195	.054	-1.071
Y3	.061	-.303	.156	-.013
Y4	.036	-.036	-.420	.050

It is noted that the unstandardized canonical correlation coefficients, for the variables of the second group (online study), when the arithmetic mean is not equal to zero and the standard deviation is not equal to (1)

Table 8: The canonical loading for the first group (face-to-face study).

Variable	1	2	3	4
X1	.983	-.173	.066	-.007
X2	.966	-.013	-.174	.189
X3	.960	.057	-.273	-.015
X4	.977	.205	.051	.006

It is noted that the canonical loading, explains the simple linear relationship between the variables of the first group (face-to-face study) and the variables of the second group (online study).

Table 9: The canonical loading for the second group (online study).

Variable	1	2	3	4
Y1	.968	.229	.072	.070
Y2	.970	.227	.056	-.066
Y3	.979	-.180	.099	-.003
Y4	.958	.048	-.281	.019

It is noted that set 2 Canonical Loading, which explains simple linear relationships between the variables of the second set (online study) and the variables of the first group (face-to-face study).

Table 10: The cross-loadings for the first group (face-to-face study).

Variable	1	2	3	4
X1	.980	-.166	.060	-.001
X2	.964	-.012	-.158	.033
X3	.958	.055	-.247	-.003
X4	.975	.196	.046	.001

It shows the correlation of each variable from the first group (face-to-face study) with the corresponding variable from the second group (online study).

Table 11: The cross-loadings for the second group (online study).

Variable	1	2	3	4
Y1	.966	.219	.065	.012
Y2	.968	.217	.051	-.011
Y3	.976	-.172	.090	-.001
Y4	.956	.046	-.255	.003

It shows the correlation of each variable from the second group (online study) with the corresponding variable from the first group (face-to-face study).

Table 12: The proportion of variance explained

Canonical Variable	Set 1 by Self	Set 1 by Set 2	Set 2 by Self	Set 2 by Set 1
1	.944	.940	.939	.934
2	.019	.017	.035	.032
3	.028	.023	.024	.020
4	.009	.000	.002	.000

It is noted that the proportion of the explained variance of the canonical variables for each of the first group (face-to-face study) itself, the second group with itself, as well as the first group with the second group (online study), and the second group with the group.

The results of the analysis can be summarized as follows:

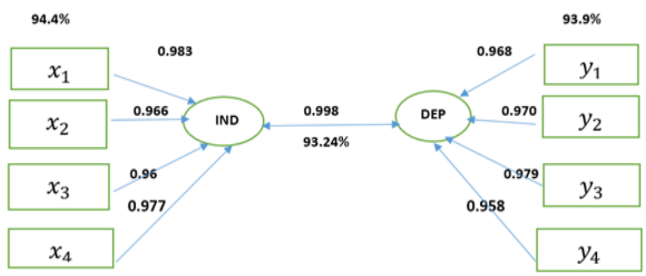

Fig.1. explains the first canonical correlation between canonical variables independents and dependents

Figure (1) shows that the first canonical correlation between canonical variables independents (x_1, x_2, x_3, x_4) and dependents (y_1, y_2, y_3, y_4) is equal (0.98), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (94.4%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (93.9%), and we notice that the variance explained between independent and dependent canonical variable is equal (93.24%). As the first canonical variable pair ($U^*{}_1, V^*{}_1$) correspondence to the largest square canonical correlation ($\lambda_{1/\sum \lambda_i}$) can be expressed as the follows:

$$U^*{}_1 = 0.983x_1 + 0.966x_2 + 0.96x_3 + 0.977x_4$$

$$V^*{}_1 = 0.968y_1 + 0.970y_2 + 0.979y_3 + 0.958y_4$$

Fig. 2. explains the first canonical correlation between canonical variables independents and dependents

Figure (2) shows that the second canonical correlation between canonical variables Independents (x_1, x_2, x_3, x_4) and dependents (y_1, y_2, y_3, y_4) is equal (0.965), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (1.9%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (3.5%), and we notice that the variance explained between independent and dependent canonical variable is equal (4.7%).As the second canonical variable pair ($U^*{}_2, V^*{}_2$) correspondence to the largest square canonical correlation ($\lambda_{2/\sum \lambda_i}$) can be expressed as follows:

$$U_2 = -0.173x_1 - 0.013x_2 + 0.057x_3 + 0.205x_4$$

$$V_2 = 0.229y_1 + 0.227y_2 - 0.180y_3 + 0.0.048y_4$$

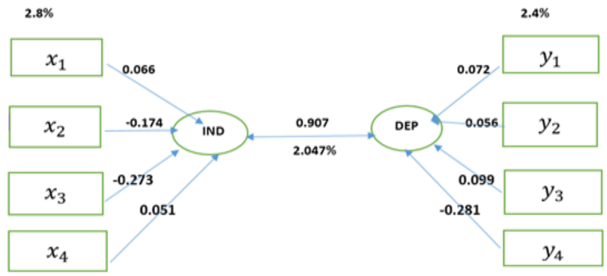

Fig. 3.explainsthe third canonical correlation between canonical variables independents and dependents

Figure (3) shows that the third canonical correlation between canonical variables independents (x_1, x_2, x_3, x_4) and dependents (y_1, y_2, y_3, y_4) is equal (0.907), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (2.8%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (2.4%), and we notice that the variance explained between independent and dependent canonical variable is equal (2.047%). As the third canonical variable pair (U^*_3, V^*_3) correspondenceto the largest square canonical correlation $(\lambda_{3/\sum \lambda_i})$ can be expressed as follows:

$$U_3 = 0.066x_1 - 0.174x_2 - 0.273x_3 + 0.051x_4$$

$$V_3 = 0.072y_1 + 0.056y_2 + 0.099y_3 - 0.281y_4$$

5 Conclusions

The first, second, and third Canonical correlations are statistically significant at the level of significance ($\alpha \leq 0.05$). The first canonical correlation between canonical variables independents and dependents is equal (0.98), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (94.4%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (93.9%), and we notice that the variance explained between independent and dependent canonical variable is equal (93.24%). The second canonical correlation between canonical variables independents and dependents is equal (0.965), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (1.9%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (3.5%), and we notice that the variance explained between independent and dependent canonical variable is equal (4.7%). The third canonical correlation between canonical variables independents and dependents is equal (0.907), and the total variance of these four variables (x_1, x_2, x_3, x_4) is (2.8%), as the total variance of these four variables (y_1, y_2, y_3, y_4) is (2.4%), and we notice that the variance explained between independent and dependent canonical variable is equal (2.047%).

Recommendation

Based on the study results, the researchers recommend to:

(1) Using the canonical correlation to evaluate Jordan's experience in online education in schools and universities.

(2) Benefiting from this research when studying the relationship between two sets of independent and dependent variables, due to the characteristics of the canonical correlation method of reducing the variables.

(3) Benefiting from the results of this research when universities decide to teach some courses, whether face-to-face or online.

(4) Conducting subsequent studies on departments and colleges that decide to teach some courses online.

Conflict of interest

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

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