Research Article https://doi.org/10.12973/eu-jer.11.4.2413

European Journal of Educational Research
Volume 11, Issue 4, 2413 - 2428.
ISSN: 2165-8714
http://www.eu-jer.com/

Multivariate Analysis of Co-creation Activities in University Education

Eirini Vardakosta* University of West Attica, GREECE
Georgios Priniotakis University of West Attica, GREECE
Michail Papoutsidakis University of West Attica, GREECE
Marisa Sigala University of West Attica, GREECE
Dimitrios Nikolopoulos University of West Attica, GREECE

Received: June 17, 2022 ▪ Revised: August 28, 2022 ▪ Accepted: October 2, 2022

Abstract: This paper investigates the viewpoints and perspectives of 179 undergraduate students engaged in a co-creation project regarding their anticipated progress, exploring, simultaneously, the affecting factors. The students attended the physics course in the Department of Industrial Design and Production Engineering at the University of West Attica, Greece. The investigation is implemented through a questionnaire that appraises the students' co-creation expectations in association with collected demographic data via twenty-two close-ended questions (Q1-Q22). Several statistical data sets are presented, including descriptive and correlation statistics and principal component and exploratory factor analyses. The majority of the replies are provided by male participants in their first year of study, with an average age of between 18 and 19. The correlation coefficient between the questions ranges from -.04 to.73, with the maximum occurring between the questions Q19 and Q20. Factor analysis justified by KMO (.862) and Bartlett's sphericity (1749.843, p= .000) tests indicates five principal components within the following factors determining the undergraduate co-creation activities: responsible behaviour, feedback, helping, tolerance, and personal interaction. The above findings may contribute to the implementation of students' co-creation as they are valuable tools for the design and pre-requisites for a successful implementation.

Keywords: *Co-creation, factor analysis, multivariate analysis, questionnaire, university students.*

To cite this article: Vardakosta, E., Priniotakis, G., Papoutsidakis, M., Sigala, M., & Nikolopoulos, D. (2022). Multivariate analysis of co-creation activities in university education. *European Journal of Educational Research, 11*(4), 2413-2428. https://doi.org/10.12973/eu-jer.11.4.2413

Introduction

Universities have been operating in an ever-changing environment in recent years due to economic, socio-cultural, and environmental pressures (Brown, 2007; Farquharson et al., 2018; Herbst, 1999; Martusewicz, 2013; McRoy & Gibbs, 2009), focusing on the changes required to keep up with data technology and innovation (Barnard & Stoll, 2010; De Freitas & Oliver, 2005), external quality and regulatory pressures (Dandridge, 2019). Due to this, appropriate teaching strategies are formulated, aiming at the active involvement, participation, productive learning but also the development of critical thinking skills of students (Karahan et al., 2022) and the entanglement of policymakers and other stakeholders. Co-creation has emerged as a new theoretical framework through which universities can bring different points of view together, improve their capacity to gather and use scarce resources, and develop a long-term solution acceptable to all stakeholders (Grönroos, 2011). Rogers and Freiberg (1994) report that during co-creation, the professor becomes a co-student, accepting students as knowledgeable and critical partners in knowledge. Later, McWilliam (2008) points out that with co-creation, the professor is faced with a new challenge: the change of his relational position to that of integration in the middle, whereby in collaboration with the student, the student becomes a co-creator in the learning procedure. According to Cook-Sather et al. (2014), co-creation is described as a collaborative, reciprocal process through which all participants have the opportunity to contribute equally, though not necessarily in the same ways, to didactic and pedagogical conception, as well as decision-making and implementation in research and analysis. Three important, dynamically connected phenomena are also described, namely, student participation, co-creation activities, and partnership.

The concept of co-creation originally started in the fields of business and marketing. Czepiel (1990), states that customer involvement in a business can lead to greater satisfaction. Prahalad and Ramaswamy (2004) characterise co-

* **Corresponding author:**
Eirini Vardakosta, Department of Industrial Design and Production Engineering, University of West Attica, Greece. ✉ irvard@uniwa.gr

creation as the development of shared values by companies and customers. This allows customers to construct experiences, define and solve common problems, and create an environment where customers can actively engage in a dialogue and emphasise variations of experiences. Other investigators perceive co-creation as a typology to highlight the variety of activities within it (Chathoth et al., 2013; O'Hern & Rindfleisch, 2010; Yi & Gong, 2013). Specifically, O'Hern and Rindfleisch (2010) express the view that there is a linkage between the development of a new product and the types of co-creation, which are grouped based on contribution and activity selection and include submitting, tinkering, collaborating, and co-designing. Chathoth et al. (2013) refer to the way in which hotel businesses can move from co-production to co-creation by presenting another typology where the two concepts are related. Later, Yi and Gong (2013) define the typology of co-creation activities in the context of running a business with its customers, which is described in two dimensions: participation and off-role behaviour. Participation includes the concepts of information seeking (Kelley et al., 1990; Kellogg et al., 1997), information sharing (Ennew & Binks, 1999), responsible behaviour (Bettencourt, 1997), and personal interaction (Ennew & Binks, 1999; Kelley et al., 1990) while off-role behaviour consists of the concepts of feedback (Groth et al., 2004), advocacy (Bettencourt, 1997; Groth et al., 2004), helping (Groth et al., 2004; Rosenbaum & Massiah, 2007) and tolerance (Lengnick-Hall et al., 2000). That is describe that eight factors determine co-creation activities. Finally, Sutarso et al. (2019) transfer the typology of Yi and Gong (2013) from the field of business to university education and, specifically, to postgraduate students from 18 public and private universities in Indonesia, where the factors that determine their co-creation activities are investigated. Co-creation was seen as a process where the student identifies with the customer, who, in collaboration with the professors, is mutually involved in the assembly and disassembly of the cultural product.

In the case of a whole-class (Bovill, 2020) the benefits of co-creation for students vary and include indicatively improved skills for future professional development, including teamwork, critical thinking, and communication skills, increased self-confidence, enthusiasm, commitment, and motivation, developing and experiencing a more equitable relationship with professors achieving learning beyond the lesson, and transitioning to new learning contexts (Bergmark & Westman, 2016; Bovill, 2014; Bovill et al., 2010; Deeley, 2014; Deeley & Bovill, 2017). But there are also challenges to a whole-class approach to co-creation, like time constraints, large classes, "sticky classes", gaps between espoused and actual practice, and sustaining co-creation that require the professor to adapt his teaching practice by learning the students to adopt different teaching approaches that are open, collaborative, interactive, and democratic (Bovill, 2020).

Accounting that co-creation has already been applied in university education at undergraduate (Clothier & Matheson, 2019), postgraduate (Bovill, 2020; Bovill et al., 2010) and doctoral level (Riva et al., 2022), this paper investigates the co-creation approach at the undergraduate level with various statistical aspects, in an attempt to contribute to further knowledge in this research field. This paper describes the ways of thinking, behaving, and acting that corresponds to co-creation activities of undergraduate students in the Department of Industrial Design and Production at the University of West Attica, Greece, participating in a co-creation project in a physics course during their first year of studies. The authors use the typology of Yi and Gong (2013) with other approaches to investigate the factors that determine the successful integration of co-creation activities of 179 participating students. Converging results are presented, providing distinct aspects of the problem and limitations and future work.

Methodology

Research Design

This paper aims to locate elements and factors related to co-creation to explore the strengths and weaknesses of the approach in its early stages and the robustness of a full co-creation implementation of the physics course. 179 students are required to complete their compulsory physics course with a co-creation approach. All these students are enrolled in the Department of Industrial Design and Production Engineering at the University of West Attica, Greece, which is a public University. Prior to the initiation of the co-creation project, all 179 students attended lectures on co-creation to get prepared for their project. After the lectures, all students completed a questionnaire about their conceptualisation and view of co-creation. The analysis of the replies to this questionnaire will be thoroughly presented in the following sections. The questionnaire is formed according to Yi and Gong (2013) and Sutarso et al. (2019) in the context of university education. In addition to demographic data (gender identity, age, year of study), it contains, 22 close-ended questions (Appendix 1) with replies on a five-point Likert scale. The replies are coded as 1 for "Disapprove", 2 for "Slightly Disapprove," 3 for "Neutral," 4 for "Slightly Approve" and 5 for "Approve". As is evident, high sum scores are associated with a high appreciation for co-creation.

Sample and Data Collection

The students filled out the questionnaire anonymously via Google Forms in the spring semester 2020-21. The anonymous responses of all 179 students are exported in ASCII format for further use.

Analysing of Data

Statistical analysis is performed in R, SPSS version 28 and SPSS AMOS version 26 softwares. The following approaches are applied:

1. Descriptive statistics, specifically partial and overall questionnaire distributions of Likert-scale data, are implemented to explore the overall tendencies of the dataset,

2. Correlation matrix is applied to delineate the dependences or associations between variables (Q1-Q22),

3. Kaiser-Meyer-Olkin (KMO) test is employed to measure the suitability of the questionnaire dataset for factor analysis,

4. Bartlett's sphericity test is usually associated with the KMO test. It is used to test the null hypothesis that the correlation matrix is an identity matrix. Note that an identity correlation matrix means that the replies to questions Q1-Q22 are unrelated and, therefore, not ideal for factor analysis,

5. Principal Components Extraction and Rotation applied to test whether the principal components (here the question replies) are independent and, therefore, uncorrelated. At first (initial phase), an eigenvalue is calculated for every component together with a corresponding percentage and cumulative variance. The eigenvalue indicates how many components explain the corresponding percentage and cumulative variance. The percentage variance is the proportion of the total variance described by each component, and the cumulative variance is the cumulative sum of all previous percentage variances. Obviously, for the first component, percentage and cumulative variances are equal. After this calculation (the extraction phase), the principal components are extracted. These are all the components that have eigenvalues equal to or greater than one. Thereafter (rotation phase), the principal components are rotated via a varimax rotation using the Bartlett score in accordance with 4 above,

6. Principal Component Analysis which contains the analysis of the principal components identified in 5 above. It is used to calculate the percentage of the total variance (percentage variance) that each component describes in the dataset. The analysis consists of two steps:

   a. Communalities Calculation: A communality is the sum of the square loadings (h^2) of each component (i.e., the reply to questions Q1-Q22). The communalities are the estimates of the variance of each component (i.e., each question reply) accounted for by all components (i.e., by all questions' replies). In another viewpoint, via a multiple linear regression model transforming the (possibly correlated) components into new (possibly uncorrelated) components, namely the principal components, the communality (h^2) is equal to the square of the Pearson's r correlation coefficient (r^2) of the multiple linear regression model that transforms the (possibly correlated) components into (possibly uncorrelated) principal components. In an alternative aspect, the communality (h^2) is the fraction of the total variance that is common among components, whereas the remaining ($1-h^2$) is the uncommon fraction of the total variance. In this aspect, a communality close to 1 suggests that the associated item explains more of the total variance than an item with a lower communality value. Typically, communality values below .40 are neglected in further analysis.

   b. Rotation of the component matrix: This is performed between the number of factors identified with a certain number of factors (columns) and the factor components (identification number of replies to questions related to the factor) (rows). The rotation is done via varimax with Kaiser normalisation.

7. The identified factors with their loadings are used for the interpretation of the students' co-creation.

8. Implementation of confirmatory factor analysis to test the suitability of the model derived from the exploratory factor analysis.

Results

Out of the 179 participating students, 114 (64%) are men and 63 (35%) women. 2 participants (1%) did not provide information of their gender identity. Ages 18 and 19 occupy percentages 39.66 and 31.84%, respectively (71.5% total). 76% of the students are in the first year of their studies. Descriptive statistics of the students' replies to the 22 questions (Q1-Q22) of the co-creation questionnaire are shown in Table 1, while Figure 1 presents the distribution of the replies in an overall manner.

Table 1. Students' Answers Regarding Co-Creation Activities (Q1-Q22)

	Students' answers				
Code	**Disapprove**	**Slightly Disapprove**	**Neutral**	**Slightly Approve**	**Approve**
Q1	1	2	15	48	113
Q2	1	21	66	48	43
Q3	0	5	35	53	86
Q4	11	29	51	34	54
Q5	4	7	35	54	79

Table 1. Continued

	Students' answers				
Code	**Disapprove**	**Slightly Disapprove**	**Neutral**	**Slightly Approve**	**Approve**
Q6	1	12	31	51	84
Q7	11	20	78	36	34
Q8	0	2	25	59	93
Q9	13	19	55	39	53
Q10	10	20	70	51	28
Q11	2	2	28	43	104
Q12	1	4	32	54	88
Q13	4	14	49	71	41
Q14	4	10	32	72	61
Q15	16	26	72	37	28
Q16	15	30	59	39	36
Q17	15	15	53	48	48
Q18	5	2	40	60	72
Q19	8	17	50	50	54
Q20	11	24	71	34	39
Q21	1	4	12	36	126
Q22	0	1	13	23	142

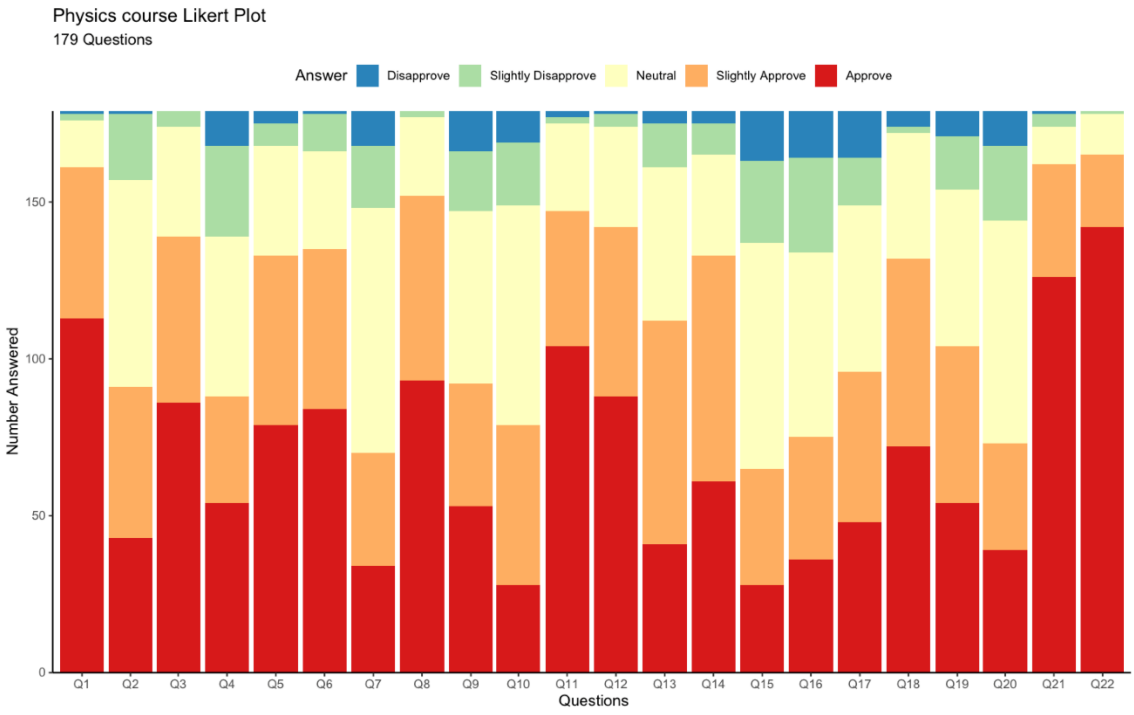

Figure 1. Students' Replies to Questions (Q1-Q22) Regarding Co-Creation Activities

The majority of the replies of Table 1 are between 3 and 5, namely between "Neutral" and "Approve". This is characteristically shown in Figure 1, where the yellow, orange, and red colours occupy the largest part of the diagram. This is a significant finding, since most of the students start with very positive altitudes and good conditions, for a completion of the course of physics with the co-creation approach. Observing the data of Table 1 the following conclusions are derived:

1. Q22 received, by far, the most positive grades from the students (142 (79%)) "Approve" rating) than any other question. Only question Q21 (Appendix 1) received similar grading (126 (70%)). The reader may recall that Q22 (Appendix 1**)** refers to the way professors are treated by their students, while question Q21 explores how students behave with each other. Interestingly, Q22 received positive to-full positive grading ("Slightly Approve" or "Approve") since 165 (92%) provided such replies.

2. Q10 received a significant neutral rating with 70 (39%) of students providing this grading. It is interesting though, that Q10 has about an equal tendency to positive replies (total 79 (44%) positive responses), whereas the negatives are much fewer (30 students). Interestingly, Q10 (Appendix 1) refers to the students' acceptance of the teaching approach.

3. Q15 also received a significant neutral rating with 72 (40%) neutral grades. As with Q10, Q15 received also more positive grades (65 (36%) responses) than the negative grades. Q15 refers (Appendix 1) Q15 refers to the "new-knowledge" approach that students show to their professors.

4. Q16 gathers the largest number of 1 or 2 grading. 45 (25%) students give such grades, namely they choose not to inform their professors about their difficulties in lessons (Appendix 1).

This may be either because they do not have the intimacy with their professors for something like this, or because they choose not to stand out from the other students.

Subsequently, the following particular cases are presented in Figure 2:

These cases are indicative, as there are other questions that present differentiations.

1. Q22 which is the question with the highest counts of positive grade 5 responses ("Approve") given by students being in their first year of study (Figure 2a) while simultaneously it has the highest counts of positive grade 5 responses ("Approve") given by male participants (Figure 2b).

2. Q7 is the question with the highest counts of neutral grade 3 responses in the age group between 18 and 19 (Figure 2c).

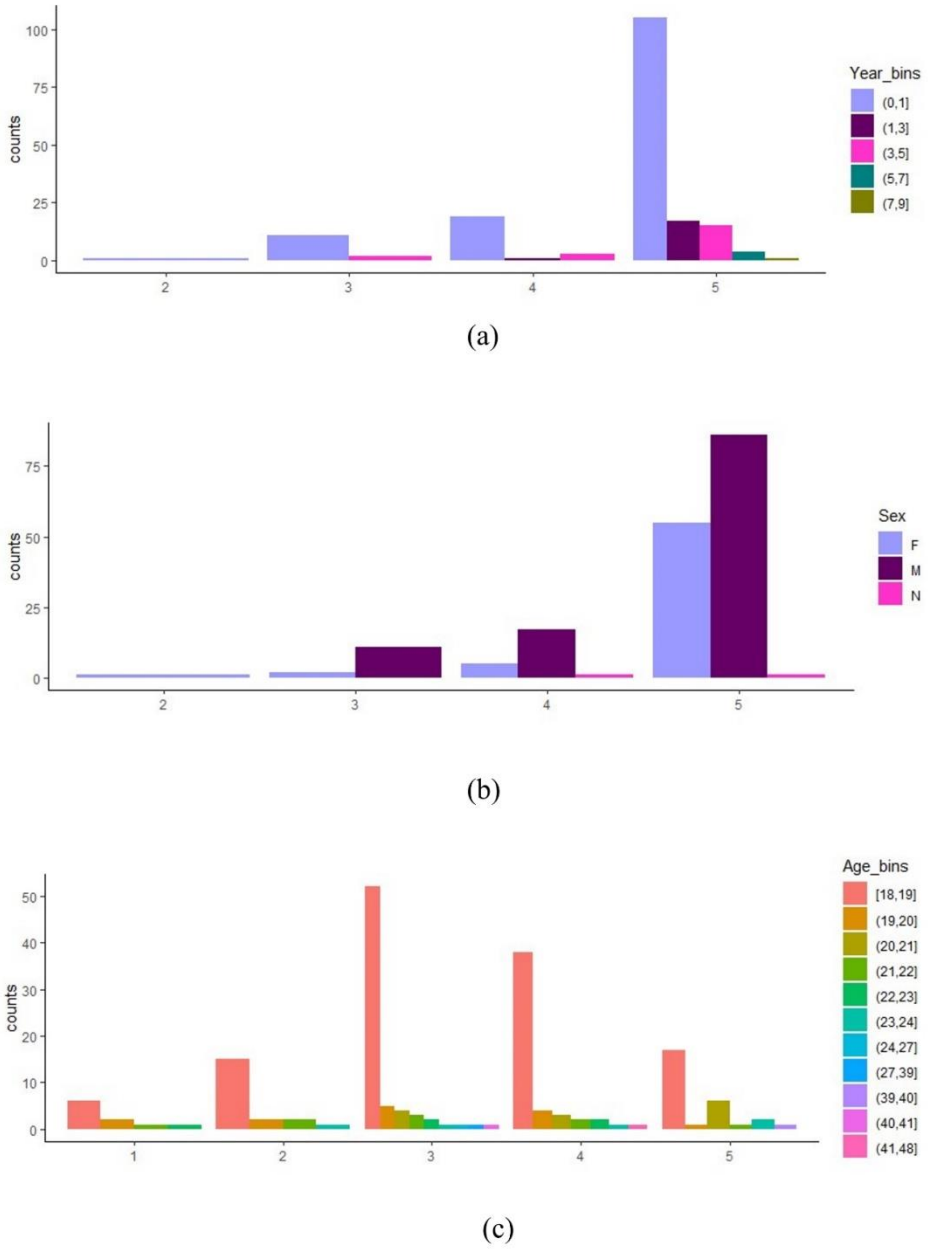

Figure 2. Special Cases of Replies to Questions: (a) Q22 With Year of Study, (b) Q22 With Gender Identity and (c) Q7 With Age

Appendix 2 presents the correlation table between all variables of the questionnaire (questions Q1-Q22). The correlation matrix investigates whether there are statistically significant correlations between the variables.

Following hypotheses were formed in this study:

H0: There is no statistically significant correlation between the variables

H1: There is a statistically significant correlation between the variables

the following correlations are of greater significance and, thus, are emphasised (the reader should also refer to Appendix 1 for the content of each question):

1. Q19 versus Q20: Correlation is statistically significant (r= .73, p = .01< .05). Rejecting H0, it can be supported that students who state that they wish to encourage their fellow students to attend the lectures tend to state that they are willing to encourage their fellow students to participate in the lectures actively,

2. Q21 versus Q22: Correlation is statistically significant (r= .69, p = .01< .05). Rejecting H0, it can be supported that individuals who state that they wish to treat their classmates with courtesy and respect tend to state that they are positive about treating their professors with courtesy and respect,

3. Q5 versus Q6: Correlation is statistically significant (r= .69, p = .01< .05). Rejecting H0, it can be supported that students who state that they wish to help their classmates with homework tend to state that they are willing to explain to their fellow students the points of the lessons that they do not understand.

4. Q12 versus Q13: Correlation is statistically significant (r= .65, p = .01< .05). Rejecting H0, it can be supported that individuals who state that they want to attend their lectures regularly tend to attend their lectures carefully and with interest.

5. Q15 versus Q16: Correlation is statistically significant (r= .65, p = .01< .05). Rejecting H0, we can say that people who stated that they wanted to turn to their professors to find suitable study sources for their courses tended to state that they were willing to inform their professors about their difficulties in lessons.

Table 2 presents the results from the KMO and Bartlett's sphericity tests. As aforementioned, both tests check the integrity of the questionnaire data for factor analysis. Especially KMO test checks how well the achieved sampling adequacy measures factorability. Precisely KMO test measures the proportion of variance among each variable (Q1-Q22) in the correlation matrix. In an alternative view, KMO test represents the degree to which the other variables in the dataset predict each observed variable and with this indicates the suitability for factor analysis. KMO varies between 0 and 1, with larger values indicating higher suitability for factor analysis. Kaiser and Rice (1974) suggest that KMO should at least exceed .50 for a correlation matrix to be suitable for factor analysis. According to this reference the KMO Values of .862 (Table 2) indicates the high suitability of the questionnaire dataset for factor analysis.

Table 2. KMO and Bartlett's Sphericity Tests

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.862
Bartlett's Test of Sphericity	Approx. Chi-Square	1.749.843
	df	231
	p	.0001

As mentioned, the Bartlett's test of Sphericity is used to test the null hypothesis that the correlation matrix is an identity matrix. The statistic is approximately chi-square distributed with df degrees of freedom and p of the chi-square statistic (Bartlett, 1951). Since p < .01 it can be supported, alternatively, that the questionnaire data are adequate for factor analysis.

The above findings indicate that an exploratory factor analysis, applied to the replies of the students to the questionnaire data, is adequate and valid in order to search for an unobserved variable (hereafter called factors) that are fewer than the 22 questions of the questionnaire and can, thus, reorganise the whole dataset and describe it alternatively. Table 3 presents the results of the method of principal components extraction and rotation. Figure 3 shows the associated scree plot, i.e., the plot of the eigenvalue of each component versus the component number.

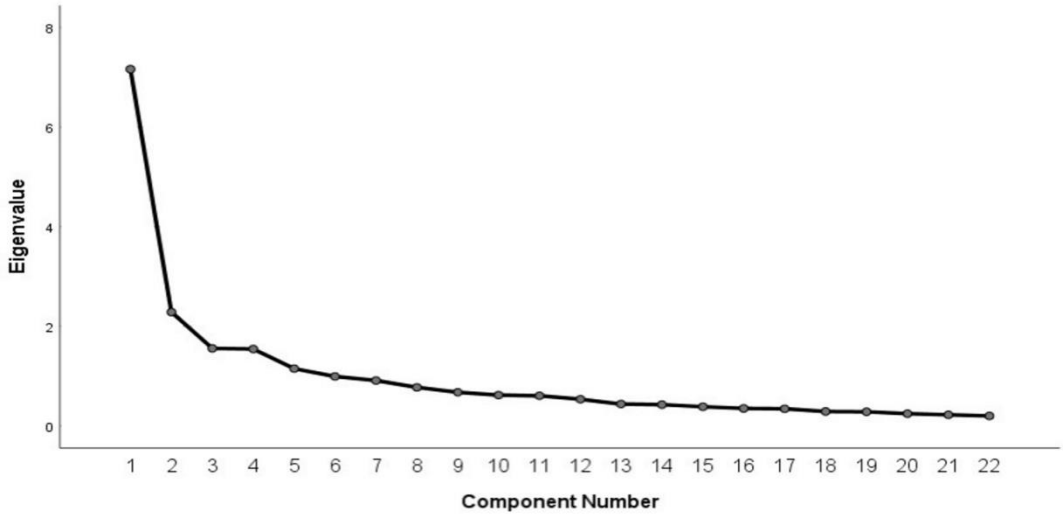

Figure 3. Scree Plot Presenting the Examined Dataset

Table 3. Varimax Rotated Component Loadings of Factors and Variance Explained for 22 Components of the Examined Dataset

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			*Rotation Sums of Squared Loadings*		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	7.163	32.559	32.559	7.163	32.259	32.259	3.390	15.411	15.411
2	2.286	10.389	42.949	2.286	10.389	42.949	3.365	15.294	30.705
3	1.557	7.076	50.024	1.557	7.076	50.024	2.741	12.458	43.163
4	1.545	7.021	57.045	1.545	7.021	57.045	2.476	11.255	54.418
5	1.150	5.228	62.273	1.150	5.228	62.273	1.728	7.854	62.273
…	…	…	…	…	…	…	…	…	…
22	…	…	…	…	…	…	…	…	…

Extraction Method: Principal Component Analysis.

In both Table 3 and Figure 3, the component number is the ascending number of each question reply (Q1-Q22). The reader should recall that the eigenvalue of each component shows how many components explain the corresponding percentage and cumulative variance. For example, component 1 (reply to Q1), explains almost as much variance as seven (eigenvalue=7.163) components (replies to questions) accounting for approximately 32.5% of the initial total variance. Component 2 explains as much variance as approximately two components (eigenvalue=2.286), describing 10.3% more proportion of the total variance (cumulative variance approximately, 32.5+10.3=42.9) and so on. Above five components, the corresponding eigenvalue is below one. This is a significant finding because it indicates that five components are enough for exploratory factor analysis. This is also supported by the fact that the five components present after the extraction phase (Table 3, columns 5, 6 and 7) explain the 62.3% of the total variance. Notably, the five-component cumulative variance remains also 62.3% after the rotating phase (Table 3, columns 8, 9 and 10). Interpreting the results from another point of view, it can be supported that the eigenvalue variation after including five different components to the exploratory factor analysis, will not add significantly more information, i.e., maximum of five different question replies are enough to define a factor in exploratory factor analysis. The latter is very significant and should be emphasised. Due to this all presented analysis hereafter is implemented with five components.

The Communalities of the components (replies to questions Q1-Q22) is shown in Table 4.

Table 4. Communality Calculation

Question	Communality (h^2)
Q1	.466
Q2	.660
Q3	.660
Q4	.693

Table 4. Continued

Question	Communality (h^2)
Q5	.763
Q6	.702
Q7	.565
Q8	.505
Q9	.646
Q10	.623
Q11	.566
Q12	.690
Q13	.702
Q14	.424
Q15	.656
Q16	.579
Q17	.618
Q18	.623
Q19	.599
Q20	.547
Q21	.714
Q22	.698

Table 5. Rotated Component Matrix. Factor Components (Columns) Versus Number of Questions Reply and Related Factor Loadings

	1	2	3	4	5
Q4	.756				
Q15	.751				
Q16	.718				
Q7	.708				
Q2	.673				
Q12		.843			
Q13		.808			
Q11		.705			
Q5			.826		
Q6			.775		
Q17			.678		
Q22				.865	
Q21				.834	
Q10					.824
Q9					.785

Table 5 presents the results from the analysis of the rotated component matrix. The results of this table are of extreme importance, and they should be stressed. On the one hand, the table shows that only five factors are needed to describe the actual statistical tendencies of the full Q1-Q22 database. On the other hand, it presents the exact question numbers that correspond to each of the one of the identified five factors that efficienly describe the questionnaire dataset. Factor 1 contains questions (with this order of significance) Q4, Q15, Q16, Q7 an Q2. Factor 2 contains Q12, Q13 and Q11 and so on. These latter results in relation to the question contents (Appendix 1), can lead to the formation of names for the five factors identified by the rotated component matrix. According to the contents of the questions, these five factors can be named as; (a) feedback (five questions), (b) responsible behaviour (three questions), (c) helping (three questions), (d) personal interaction (two questions), and (e) tolerance (two questions).

Table 6 presents the five factors with their suggested names versus the actual question content which is shown in Appendix 1 and the factor loadings of Table 5. It can be observed that factor loadings range from .673 (“I am willing to make my own comments when the professors explain part of the course”) to .865 ("I treat my professors with courtesy and respect”) (please refer also to Appendix 1).

Table 6. Student Co-Creation Activities Factors

Factors	Questions	Loadings
Feedback	I turn to my professors to find suitable study sources for my courses.	.751
	I report my ideas and opinions about the lessons to my professors.	.756
	I inform my professors about my difficulties in the lessons.	.718
	I am willing to make my own comments when the professors explain part of the course.	.673
	With my participation, I help the professors in conducting the courses.	.708
Responsible Behaviour	I will complete the assignments given to me by my professors.	.705
	I regularly attend my lectures.	.843
	I attend my lectures carefully and with interest.	.808
Helping	I help my classmates with homework.	.826
	I explain to my fellow students the points of the lessons that they do not understand.	.775
	I inform my classmates about my difficulties in lessons.	.678
Personal Interaction	I treat my classmates with courtesy and respect.	.834
	I treat my professors with courtesy and respect.	.865
Tolerance	If a lecture is rescheduled at an inconvenient time for me, I will accept it.	.785
	If my professors do not teach the course according to the way I would like to teach it, I will accept it.	.824

The graphical approach of the confirmatory factor analysis for the model of five co-creation factors is presented by using SPSS AMOS version 26 is presented in Appendix 3.

Table 7 presents the main indices of the model performing confirmatory factor analysis as well as the acceptable values. These indices are the Chi-square statistic measure (CMIN), the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and other measures so as to certify the performance of the model under consideration.

Table 7. Model Fit Measures and Acceptable Values

Measure	Estimate	Threshold	Terrible	Acceptable	Excellent	Interpretation
CMIN	163.638	--	--	--	--	--
DF	80	--	--	--	--	--
CMIN/DF	2.045	Between 1 and 3	>5	>3	> 1	Excellent
CFI	.912	>.95	<0.90	< 0.95	> 0.95	Acceptable
RMSEA	.077	<.06	> 0.08	> 0.06	< 0.06	Acceptable
PClose	.006	>.05	<0.01	< 0.05	> 0.05	Terrible

Discussion

According to the above, for all questions (Q1-Q22) about co-creation activities, the positive answers with grades 4 or 5 "Slightly Approve" or "Approve" are much more than the negative grades, 1 or 2 “Disapprove” or “Slightly Disapprove”. However, special attention should be paid by professors to questions that indicate possible weaknesses of students such as Q10, Q15 and Q16 mentioned above. The positive results are also confirmed through the exploratory factor analysis, where it is found that five factors determine the co-creation activities. These factors are feedback, responsible behaviour, helping, personal interaction and tolerance. Feedback is the factor that reflects the degree to which a student provides feedback on the learning process through activities such as participation in the lesson, reporting ideas and opinions about the course, commenting, informing their professors of any difficulties, and their guidance in finding suitable study sources. Responsible behaviour is the factor that indicates the degree to which the student completes the tasks given by the professor attends regularly, but also with attention and interest, the lectures of the related courses. Helping is the factor that relates to the extent to which the student assists the fellow students in understanding or doing homework but also reports the difficulties they face in the lessons. Personal interaction is the factor that refers to the relationship of students with each other but also with professors who are retain courtesy and respect. Finally, tolerance refers to the degree to which the student is tolerant of events such as rescheduling a lecture at an inconvenient time or if the way the course is taught is not what the student would expect.

Based on the above, the factors extracted from the analysis of the questionnaire confirmed five of the eight co-creation activities formulated by Yi and Gong (2013) for the business space and applied later by Sutarso et al. (2019) in the context of university education. The existence of the above five factors is a very important condition for the completion of the physics course with co-creation. It should be stressed that Sutarso et al. (2019) report five factors as well. These factors are the strong points of the students' behaviour, through which, in collaboration with the professors, the

students maintain and further strengthen the co-creation activities. It may also be useful, prior to or during any co-creation approach, if professors could additionally consider the possible weaknesses of some participants to be able to intervene actively and undertake corrective actions to improve them. Moreover, co-creation is an approach where the professors open up the learning and teaching experience to negotiate and redesign the course each time a new class of students is met, responding to the students' needs and adopting a potential commitment to the profession with each group (Bovill, 2020).

The authors comparing the factors defining co-creation activities between postgraduate students, as investigated by Sutarso et al. (2019), and undergraduate students in the course of Physics found that there is an identification between four of the five factors, specifically those of feedback, responsible behaviour, helping, and tolerance. Nevertheless, there is one factor that differs, which for postgraduate students is seeking information, while for undergraduate students it is personal interaction. The existence of the factor of seeking information for postgraduate students could be justified due to their undergraduate studies and previous experience in university education, which is absent from the undergraduate students, most of whom are only in the second semester of their academic studies. The existence of the factor of personal interaction for undergraduate students could be justified due to the importance given by them in the field of relationships, mainly with fellow students and their professors, with whom they will spend at least five years together. On the contrary, the duration of postgraduate studies is much shorter (one and two years) and does not allow for the establishment of strong bonds between students and professors. Finally, Sutarso et al. (2019) conducted their study in 18 postgraduate programs, referring to a broader study framework compared to the authors' study, which is defined in the context of an undergraduate course.

However, the appropriateness of the model of five co-creation factors resulting from the implementation of exploratory factor analysis was investigated through confirmatory factor analysis and indices calculation.

Initially, the model which is being considered and the independence model were statistically significant ($p < .05$). The standardised regression weights defined a threshold value as a minimum level below which the items were not loaded properly. The minimum threshold level of .50 is required, or sometimes even .70, in order that the assumption is not violated. Consequently, all the items were loaded properly as all values were significantly high (Appendix 3). According to table 7, the index CMIN for the degrees of freedom (DF) is considered particularly satisfactory (excellent). Nevertheless, based on the p of CMIN ($p=.00$) is observed a statistically significant difference between the model under consideration and the saturated model. Also, the indicators RMSEA and CIF are considered acceptable despite the value of RMSEA in reference its cut-off ($p< .01$) threshold. Note that the confirmatory factor analysis provides alternative viewpoints, yet it does not cancel all previous findings with the statistical tests already presented.

Despite any weaknesses in the produced model, the present work identified essential elements that can affect the design and successful fulfillment of co-creation in university education. These elements are useful design tools and pre-requisites for the implementation of the co-creation.

Conclusions

From the exploratory factor analysis, five factors determine the co-creation activities of the undergraduate students in the course of physics: feedback, responsible behaviour, helping, personal interaction, and tolerance. Based on the results of Figure 1 and the factor analysis, the participating students have satisfactory conditions to complete the course of physics with the co-creation approach. Professors should consider the findings of the present research and repeat it each time they meet a new class of students, in order to maintain and increase the students' strengths and reinforce any weaknesses, so that a whole-class co-creation approach can be implemented. The start of co-creation could assist the first semesters of students' studies, and if continued in other semesters, or even the whole curriculum, could help the progress of the entire department. Thus, providing all the necessary time both for the institutional processes that must accompany the framework and for teachers, students, and interested members to adapt to the specific way of working.

Recommendations

Universities, through their senior leadership, should provide support to co-creation teams. This support includes the availability of time, space, tools, and small-scale funding, as well as the appointment of key people at the university, who will contribute to the implementation of new strategies in co-creation initiatives. Finally, an essential role in the success of co-creation is to be played by the professors, who should be open both to the development of new skills and to the reformulation of their teaching practice, processes that require time and painstaking effort. However, carrying out the whole process helps the academic staff develop their experience and scientific and research abilities.

In particular, future research could use combinatorial and qualitative research methods to illustrate additional dimensions. The variables that can be studied for the extension of this topic are the family environment, the economic situation, or other higher education structures. Also, the findings of this study come from a specific course, that of physics. The study could be applied to other courses in the curriculum in order to compare the results produced. Finally, such studies could be applied in addition to the educational context. Of particular interest and future research is the study of co-creation in the administrative context, which is one of the critical factors in achieving the goals of

University education and, at the same time, an essential element of its quality, since it ensures the conditions for its smooth and most efficient operation.

Limitations

Using exclusively quantitative research methods is both a recommendation and a limitation of this study. Also, a limitation of this study is the fact that the majority of students are in their first year of study, so their views and perspectives are likely to have been affected to a considerable extent by their previous experiences in collaborative learning environments in high school. It should be noted that the operating framework of higher education is completely different. Finally, in this study, there is no investigation of the produced results of the participating students, regarding co-creation, in terms of gender identity, age, or year of study.

Funder

The research received support by the special Account for Research Grants (ELKE) of University of West Attica.

Authorship Contribution Statement

Vardakosta: Concept and design, data acquisition, drafting manuscript, statistical analysis. Priniotakis: Critical revision of manuscript, final approval. Papoutsidakis: Critical revision of manuscript, final approval. Sigala: Critical revision of manuscript, final approval. Nikolopoulos: Drafting manuscript, critical revision of manuscript, statistical analysis, supervision, technical support, final approval.

References

Barnard, M., & Stoll, N. (2010). *Organisational change management: A rapid literature review.* Centre for Understanding Behaviour Change.

Bartlett, M. S. (1951). The effect of standardization on a Chi-square approximation in factor analysis. *Biometrika*, *38*(3-4), 337-344. https://doi.org/10.1093/biomet/38.3-4.337

Bergmark, U., & Westman, S. (2016). Co-creating curriculum in higher education: Promoting democratic values and a multidimensional view on learning. *International Journal for Academic Development*, *21*(1), 28–40. https://doi.org/10.1080/1360144X.2015.1120734

Bettencourt, L. (1997). Customer voluntary performance: Customers as partners in service delivery. *Journal of Retailing, 73*(3), 383–406. https://doi.org/10.1016/S0022-4359(97)90024-5

Bovill, C. (2014). An investigation of co-created curricula within higher education in the UK, Ireland and the USA. *Innovations in Education and Teaching International*, *51*(1), 15-25. https://doi.org/10.1080/14703297.2013.770264

Bovill, C. (2020). Co-creation in learning and teaching: The case for a whole-class approach in higher education. *Higher Education, 79*(6), 1023–1037. https://doi.org/10.1007/s10734-019-00453-w

Bovill, C., Aitken, G., Hutchison, J., Morrison, F., Roseweir, K., Scott, A., & Sotannde, S. (2010). Experiences of learning through collaborative evaluation from a postgraduate certificate in professional education. *International Journal for Academic Development, 15*(2), 143-54. https://doi.org/10.1080/13601441003738343

Brown, R. (2007). The market' and institutional change. *Perspectives: Policy and Practice in Higher Education, 11*(2), 31–32. https://doi.org/10.1080/13603100701258941

Chathoth, P., Altinay, L., Harrington, R. J., Okumus, F., & Chan, E. S. W. (2013). Co-production versus co-creation: A process based continuum in the hotel service context. *International Journal of Hospitality Management, 32*(1), 11–20. https://doi.org/10.1016/j.ijhm.2012.03.009

Clothier, A., & Matheson, D. (2019). Using co-creation as a pedagogic method for the professional development of students undertaking a BA (Hons) in education studies. *Journal of Further and Higher Education, 43*(6), 826–838. https://doi.org/10.1080/0309877X.2017.1409344

Cook-Sather, A., Bovill, C., & Felten, P. (2014). *Engaging students as partners in teaching and learning: A guide for faculty*. Jossey-Bass.

Czepiel, J. (1990). Service encounters and service relationships: Implications for research. *Journal of Business Research, 20*(1), 13–21. https://doi.org/10.1016/0148-2963(90)90038-F

Dandridge, N. (2019). The office for students: Reflections on our first year. *Perspectives: Policy and Practice in Higher Education, 23*(4), 158–161. https://doi.org/10.1080/13603108.2019.1591538

Deeley, S. J. (2014). Summative co-assessment: A deep learning approach to enhancing employability skills and attributes. *Active Learning in Higher Education*, *15*(1), 39-51. https://doi.org/10.1177/1469787413514649

Deeley, S. J., & Bovill, C. (2017). Staff student partnership in assessment: Enhancing assessment literacy through democratic practices. *Assessment and Evaluation in Higher Education*, *42*(3), 463–477. https://doi.org/10.1080/02602938.2015.1126551

De Freitas, S., & Oliver, M. (2005). Does e-learning policy drive change in higher education?: A case study relating models of organisational change to e-learning implementation. *Journal of Higher Education Policy and Management 27*(1), 81–96. https://doi.org/10.1080/13600800500046255

Ennew, C., & Binks, M. (1999). Impact of participative service relationships on quality, satisfaction and retention: An exploratory study. *Journal of Business Research, 46*(2), 121–132. https://doi.org/10.1016/S0148-2963(98)00016-2

Farquharson, L., Sinha, T., & Clarke, S. (2018). Researching organisational change in higher education: A holistic tripartite approach*. The Electronic Journal of Business Research Methods, 16*(3), 150–161. https://bit.ly/3M3evQs

Grönroos, C. (2011). Value co-creation in service logic: A critical analysis. *Marketing Theory*, *11*(3), 279–301. https://doi.org/10.1177/1470593111408177

Groth, M., Mertens, D., & Murphy, R. (2004). Customers as good soldiers: Extending organizational citizenship behavior research to the customer domain. In D. Turnipseed (Ed.), *Handbook of organizational citizenship behavior* (pp.415–433). Nova Science Publishers.

Herbst, M. (1999). Change management: A classification. *Tertiary Education and Management, 5*(2), 125–139. https://doi.org/10.1080/13583883.1999.9966986

Kaiser, H., & Rice, J. (1974). Little Jiffy, Mark IV. *Educational and Psychological Measurement*, *34*(1), 111-117. https://doi.org/10.1177%2F001316447403400115

Karahan, E., Bozan, M. A., & Akçay, A. O. (2022). The analysis of prospective counselors' instructional designs to develop critical thinking skills. *Educational Studies: A Journal of the American Educational Studies Association, 58*(1), 95-113*.* https://doi.org/10.1080/00131946.2021.1994973

Kelley, S., Donnelly, J., & Skinner, S. (1990). Customer participation in service production and delivery. *Journal of Retailing, 66*(3), 315–335.

Kellogg, D., Youngdahl, W., & Bowen, D. (1997). On the relationship between customer participation and satisfaction: Two frameworks. *International Journal of Service Industry Management, 8*, 206–219. https://doi.org/10.1108/09564239710185406

Lengnick-Hall, C., Claycomb, V., & Inks, L. (2000). From recipient to contributor: Examining customer roles and experienced outcomes. *European Journal of Marketing, 34*(3/4), 359–383. https://doi.org/10.1108/03090560010311902

Martusewicz, R. (2013). When the political gets personal: Social foundations and university politics in hard times. *Educational Studies: A Journal of the American Educational Studies Association, 49*(6), 481-484. https://doi.org/10.1080/00131946.2013.846595

McRoy, I., & Gibbs, P. (2009). Leading change in higher education*. Educational Management Administration & Leadership, 37*(5), 687–704. https://doi.org/10.1177/1741143209339655

McWilliam, E. (2008). Unlearning how to teach. *Innovations in Education and Teaching International*, *45*(3), 263-269. https://doi.org/10.1080/14703290802176147

O'Hern, M. S., & Rindfleisch, A. (2010). Customer co-creation: A typology and research agenda. In N. K. Malhotra (Ed.), *Review of marketing research* (Vol. 6, pp.84–106). Emerald Group Publishing Limited. https://doi.org/10.1108/S1548-6435(2009)0000006008

Prahalad, C. K., & Ramaswamy, V. (2004). *The future of competition: Co-creating unique value with customers*. Harvard Business School Press. https://doi.org/10.1108/10878570410699249

Riva, E., Gracia, L., & Limb, R. (2022). Using co-creation to facilitate PhD supervisory relationships, *Journal of Further and Higher Education*, *46*(7), 913-930. https://doi.org/10.1080/0309877X.2021.2021158

Rogers, C., & Freiberg, J. (1994). *Freedom to learn* (3rd ed.). Merrill.

Rosenbaum, M., & Massiah, C. (2007). When customers receive support from other customers: Exploring the influence of intercustomer social support on customer voluntary performance. *Journal of Service Research, 9*(3), 257–270. https://doi.org/10.1177/1094670506295851

Sutarso, Y., Halim, R. E., Balqiah, T. E., & Tjiptoherijanto, P. (2019). Understanding customer co-creation activities in higher education: Groupings, characteristics and implications. *International Journal of Business and Society, 20*(1), 42–56. https://bit.ly/3dtMKDM

Yi, Y., & Gong, T. (2013). Customer value co-creation behavior: Scale development and validation. *Journal of Business Research, 66*(9), 1279-1284. https://doi.org/10.1016/j.jbusres.2012.02.026

Appendices

Appendix 1

Table A1. Question Number (Q1-Q22) and Content

Code	Content
Q1	I would like to receive feedback from my professors on my progress or work in the lessons.
Q2	I am willing to make my own comments, when the professors explain part of the course.
Q3	I am positive in asking my professors for further explanations for part of the courses.
Q4	I report my ideas and opinions about the lessons to my professors.
Q5	I help my classmates with homework.
Q6	I explain to my fellow students the points of the lessons that they do not understand.
Q7	With my participation, I help the professors in conducting the courses.
Q8	I accept any different views regarding the courses of my professors or fellow students.
Q9	If a lecture is rescheduled at an inconvenient time for me, I will accept it.
Q10	If my professors do not teach the course according to the way I would like to teach, I will accept it.
Q11	I will complete the assignments given to me by my professors.
Q12	I regularly attend my lectures.
Q13	I attend my lectures carefully and with interest.
Q14	I am looking for information about my courses from various sources.
Q15	I turn to my professors to find suitable study sources for my courses.
Q16	I inform my professors about my difficulties in the lessons.
Q17	I inform my classmates about my difficulties in lessons.
Q18	I am willing to share information, knowledge and experiences with my professors and fellow students.
Q19	I encourage my fellow students to attend the lectures.
Q20	I encourage my fellow students to actively participate in the lectures.
Q21	I treat my classmates with courtesy and respect.
Q22	I treat my professors with courtesy and respect.

Appendix 2

Table A2. Correlation Matrix Between Questions Q1-Q22

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22
Q1	1.00	.26	.34	.29	.16	.21	.19	.24	-.02	.10	.34	.27	.28	.31	.19	.23	.14	.23	.42	.35	.25	.33
Q2	.26	1.00	.52	.58	.33	.21	.44	.20	-.04	.04	.19	.07	.10	.19	.29	.31	.32	.41	.17	.22	.08	.13
Q3	.34	.52	1.00	.50	.33	.31	.34	.37	.08	-.04	.26	.28	.24	.31	.23	.27	.29	.38	.26	.24	.33	.34
Q4	.29	.58	.50	1.00	.36	.32	.56	.28	-.01	-.01	.22	.14	.27	.22	.44	.40	.39	.47	.31	.38	.04	.12
Q5	.16	.33	.33	.36	1.00	.69	.40	.40	.16	.16	.31	.12	.28	.29	.29	.29	.51	.55	.42	.28	.31	.26
Q6	.21	.21	.31	.32	.69	1.00	.42	.38	.22	.24	.38	.29	.36	.32	.27	.26	.41	.54	.48	.36	.27	.23
Q7	.19	.44	.34	.56	.40	.42	1.00	.28	.08	.14	.19	.16	.31	.23	.47	.44	.31	.41	.29	.38	.05	.07
Q8	.24	.20	.37	.28	.40	.38	.28	1.00	.21	.16	.26	.28	.27	.34	.20	.19	.28	.42	.35	.30	.47	.43
Q9	-.02	-.04	.08	-.01	.16	.22	.08	.21	1.00	.42	.09	.06	.08	.12	.04	.07	.00	.12	.19	.25	.24	.21
Q10	.10	.04	-.04	-.01	.16	.24	.14	.16	.42	1.00	.13	.10	.13	.14	.16	.04	-.03	.20	.24	.19	.09	.12
Q11	.34	.19	.26	.22	.31	.38	.19	.26	.09	.13	1.00	.57	.52	.37	.18	.26	.30	.28	.42	.31	.29	.29
Q12	.27	.07	.28	.14	.12	.29	.16	.28	.06	.10	.57	1.00	.65	.36	.15	.23	.15	.24	.38	.28	.40	.35
Q13	.28	.10	.24	.27	.28	.36	.31	.27	.08	.13	.52	.65	1.00	.46	.35	.36	.26	.37	.49	.43	.32	.28
Q14	.31	.19	.31	.22	.29	.32	.23	.34	.12	.14	.37	.36	.46	1.00	.48	.35	.29	.39	.34	.30	.29	.22
Q15	.19	.29	.23	.44	.29	.27	.47	.20	.04	.16	.18	.15	.35	.48	1.00	.65	.33	.40	.29	.38	.03	.03
Q16	.23	.31	.27	.40	.29	.26	.44	.19	.07	.04	.26	.23	.36	.35	.65	1.00	.35	.33	.36	.40	.09	.12
Q17	.14	.32	.29	.39	.51	.41	.31	.28	.00	-.03	.30	.15	.26	.29	.33	.35	1.00	.51	.39	.37	.09	.12
Q18	.23	.41	.38	.47	.55	.54	.41	.42	.12	.20	.28	.24	.37	.39	.40	.33	.51	1.00	.45	.41	.31	.36
Q19	.42	.17	.26	.31	.42	.48	.29	.35	.19	.24	.42	.38	.49	.34	.29	.36	.39	.45	1.00	.73	.35	.35
Q20	.35	.22	.24	.38	.28	.36	.38	.30	.25	.19	.31	.28	.43	.30	.38	.40	.37	.41	.73	1.00	.22	.21
Q21	.25	.08	.33	.04	.31	.27	.05	.47	.24	.09	.29	.40	.32	.29	.03	.09	.09	.31	.35	.22	1.00	.69
Q22	.33	.13	.34	.12	.26	.23	.07	.43	.21	.12	.29	.35	.28	.22	.03	.12	.12	.36	.35	.21	.69	1.00

Appendix 3

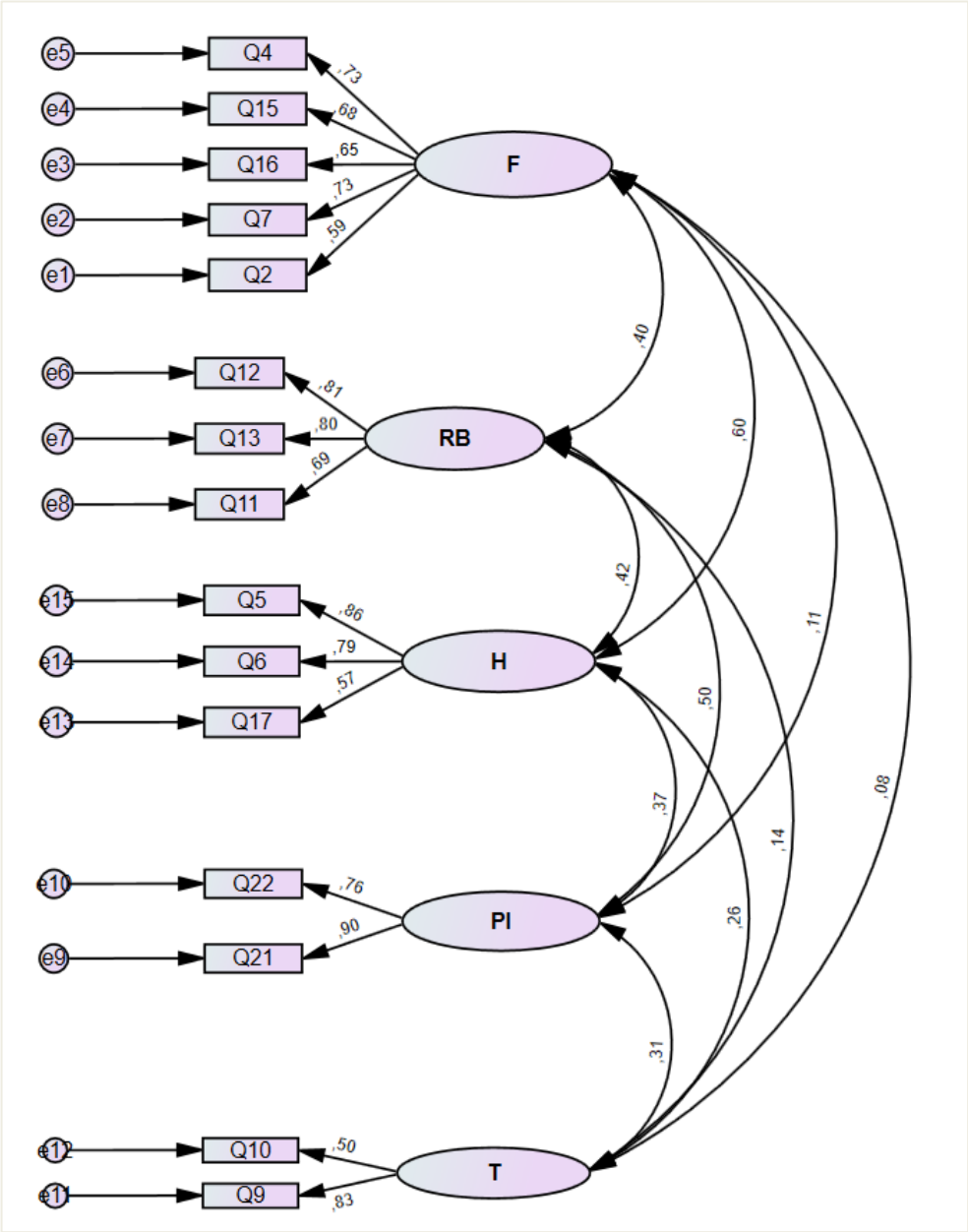

Figure A1. The Graphical Approach of Confirmatory Factor Analysis for the Model of Five Co-Creation Factors.