On the Competency Profiles of Graduates

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Abstract: In this paper a competency profile of university/college graduates is developed. A survey is conducted to measure the satisfaction of the entire teaching process with respect to 26 attributes at a local higher educational institution based on students' opinion. The research was supported by a multivariate statistical method called correspondence analysis. Some details of its mathematical background and the interpretation of the results are also discussed.

Keywords: competency profile, correspondence analysis, cross-tabulations

1 Introduction

Organizations have changed rapidly over the last decade and they are likely to continue to evolve in the nearest future. University and college graduates should no longer expect stability and a linear career progress. They need to be alert to the growing and varied range of graduate opportunities, often in non-traditional areas. A tendency in the job market is well observable: more and more graduates show up in this relatively narrowing market and less and less institutions are able to conform to the contemporary challenges of this market. Graduates are being employed even in areas that were formerly staffed by non-graduates. Firms and enterprises want people who could be effective in this changing world in a global sense. They want now, and in the foreseeable future, intelligent, flexible adaptable employees who are quick to learn and who can deal with change.

Employers want people who can rapidly fit in to the workplace culture, work in teams, exhibit good interpersonal skills, communicate well, take on responsibility for an area of work, and perform efficiently and effectively to add value to the organization—they want adaptive recruits. Employers want people who exhibit an ability to learn and add to knowledge and skill and the ability to use their knowledge and skills in face of change. They would like to have people who have bright ideas, who are able to communicate them to others, develop them in teams and persuade colleagues to attempt new approaches—they want adaptable people. Ultimately, employers want well educated human resource to anticipate and lead
change, in order to help executives transform their organizations. People who can use higher-level skills, such as analysis, critique, synthesis, and multi-level communication to facilitate innovative teamwork—they want transformative employees.

Higher education needs to be aware of the changing nature of the workplace and of the requirements of employing organizations. Universities need to be responsive to these changes and demands. Institutions have a great responsibility to its principal stakeholders (students) to equip them with more than a profound knowledge of an academic subject area. Younger, full-time students leave university with little idea of the nature and culture of the workplace and find it initially difficult to adjust. This period of adjustment - the time it takes for a graduate to become effective in the workplace - is, increasingly, a cost that graduate employers are unable or unwilling to bear. Many small and medium-sized companies want new recruits to be effective from the outset. The implication of this is that higher education programs will need to much better prepare graduates for workplace requirements and culture.

Higher education should continue to strive to enhance and empower all graduates as critical reflective, transformative people. These latter elements of higher education constitute, arguably, the essence of any undergraduate and graduate programs. Graduates must be intelligent, rounded people who have a depth of understanding, can apply themselves, take responsibility and develop their role in the organization — to be educated rather than trained. For young people, an extended period away from home helps them become mature, develop a broader perspective, enhance interpersonal skills and self-confidence. Such an environment, developed in a university setting, will be increasingly important in organizational structures and in the future global economy where it will be necessary to be sensitive to cultural sensibilities and local politics.

In essence, employers expect a degree to provide a profound, broad education rather than attempt to train someone for a specific job. In some cases, particular knowledge and understanding of a subject area is a bonus, as are specific technical skills. An understanding of the world of work, some commercial awareness, some appreciation of work culture and the ability to work in teams, communicate well and exhibit confidence (but not arrogance) in interpersonal relations is a considerable enhancement. So higher education needs to work with employers to identify what is necessary in a graduate education to develop added value. Indeed, most employers would like to develop closer links with higher education. There are practical constraints that restrict the amount of effort that can be put into developing such links. Most employers see links in terms of recruitment and training. Some see links in terms of providing placement experience. Few consider it their role to directly or indirectly affect curriculum content and delivery, although some think it would be mutually beneficial if employers became more involved in programs of study, offering guest lecturers, hosting open days, and so on.
Most people and most students nowadays believe that it is one of higher education's purposes to prepare students well for working-life. Employers and their representatives consistently say that, to succeed at work, graduates must develop a range of personal and intellectual attributes beyond those traditionally made explicit in programs of study in higher education institutions. There is increasing pressure on higher education to contribute directly to economic regeneration and growth, industrial productivity and hence competitiveness. These are becoming increasingly important and are likely to be more pressing in the working world of the nearest future.

The research reported here had explored the views of a wide range of recent graduates at the Budapest Tech to identify the nature and extent of the knowledge, abilities and skills that graduates will need to be successful at work. The research, aimed at helping students towards success at work, is designed to provide a firmer base on which higher education might respond to employer perceptions.

2 Methodology of the Research-Correspondence Analysis

In this Section a brief overview of this multivariate statistical method is presented. For a comprehensive description of this technique we refer to the classic texts by Greenacre [6] and Benzecri [3]. Cross-tabulation of categorical data is perhaps the most commonly encountered simple form of analysis in applied research. Correspondence analysis (CA) is a descriptive technique of factoring categorical variables and displaying them in a property space which maps their association in two or more dimensions. It can be used where the contingency table approach is less effective due to the very complex large tables. So CA starts with tabular data, usually two-way cross-classifications. A measure of distance between any two points, is defined, where points are values (categories) of the discrete variables. CA employs chi-square distances to calculate the dissimilarity (or similarity) between the frequencies in each cell of a contingency table. The cross-tabulation table of frequencies is standardized, so that the relative frequencies across all cells sum to unity. The goal of such an analysis is to represent the entries in the table of relative frequencies in terms of the distances between particular rows and/or columns in a low-dimensional space, in usually two dimensions. This is achieved by factoring the basic structure (through singular value decomposition) of the chi-square distance matrix, resulting in a set of row vectors, column vectors and singular values [6]. In this step, the procedure requires the researcher to choose between different methods of normalization. Finally, the CA scales the vectors to create scores for each participant and each variable. These scores are plotted in a visual display, by showing which category values are close together. The interpretive strength of CA lies with its representation of low-dimensional
solutions in these graphical displays, which permit the researcher to make comparisons between row variables and/or between column variables (after principal normalization), and between row and column variables (after symmetrical normalization) in their relative placement in shared low-dimensional space.

The differences between the methods of creating the graphical representations has caused debate in the literature about the most appropriate choice of normalization and methods of interpretation of the visual display [5], [8], [13]. Gabriel [5] calculated goodness-of-fit for the various forms of graphical representation available in CA. He concluded that researchers who have a specific interest in actual magnitudes of difference between row variables, or between column variables should choose the appropriate row or column principal normalization. However, researchers whose interest lies in comparing the general orientation of row points and column points in terms of the relative magnitude of the distance, rather than visualizing actual magnitudes, are well served by the symmetrical normalization option. The symmetric biplot, in addition to its optimal fit of the data, proportionally fits the form and the variance almost optimally and is an excellent candidate for general usage, unless one requires representation of the actual magnitudes [5, p. 435].

Examples of applications of CA can be found in various fields of interest, e.g., in medical research [7], for students’ and teachers’ cognitions about good teachers [1], for higher education institution image [12], for personalities [13], and in marketing research [2].

The formal description of the mathematics of CA is now presented (see Greenacre [1] for more details). Suppose that we are given a data matrix $N$ with $I$ rows and $J$ columns. Elements of this matrix are denoted by $n_{ij}$, $i=1,\ldots,I$, $j=1,\ldots,J$. By denoting the elements of the vectors $r$ and $c$ represent the sums of the rows and the columns, respectively; they are termed row and column masses, and $1$ is a (column) vector with all entries 1. Observe that the sum of the table entries is equal to unity. $R$ and $C$ are called row and column profiles, respectively. Matrix $Q$ contains the differences between the entries of the matrix of the relative frequencies, $P$, and the corresponding products of the row and column totals (i.e. the differences between the observed and the expected frequencies). By introducing the following expressions

\begin{align*}
    n &= \sum_{i=1}^{I} \sum_{j=1}^{J} n_{ij}, \quad P = N/n, \quad r = P1, \quad c = P^T1 \\
    D_r &= diag(r), \quad D_c = diag(c) \\
    R &= D_r^{-1}P, \quad C = D_c^{-1}P^T \\
    Q &= P - rc^T
\end{align*}
by the traces of the above matrices the $1/n$ multiples of the values of the chi-square statistic with degrees of freedom $(I-1)(J-1)$ are derived. These are called the total inertia of rows and columns, respectively (the integral of mass times the squared distance to the centroid). The total inertia, $in(I,J)=\chi^2/n$, is one measure of homogeneity/heterogeneity of the contingency table. Homogeneity means that there is no row-column association (no dependencies). In other way around, if all elements of the row (or column) profiles are close to the average row (or column) profile then the table is homogeneous. Otherwise the table is heterogeneous.

Next we pose the following task: Given a set of multivariate observations, determine a rotated axis such that the variable thereby defined as a linear combination of the original variables has maximum variance (a set of linear transformations corresponding to the principal-axes rotation). It can be proven that $\chi^2=X^T\Sigma^{-1}X$. In this quadratic form, $X$ represents the deviation-score matrix whereas $\Sigma$ represents the covariance matrix. Applying the above defined principal-axes rotation to our problem the variance maximization means that we look for a (column) vector $g$ ($g$ should be premultiplied by the row profile) so that the largest possible variance is to be found which maximizes the quadratic form

$$(Rg - 1c^Tg)^T D_c (Rg - 1c^Tg) \rightarrow \text{max}$$

In order to get nontrivial solutions to this maximization problem let the following side conditions be imposed for the unknown vector $g$ (let its weighted norm be equal to 1 and its weighted mean 0, where the weights are the column masses)

$$g^T D_c g = 1, \quad c^T g = 0$$

Since now, by introducing a new variable $y$, the normalization yields $c^T y = r^T R y = 0$, we can rewrite the maximization problem as

$$(Rg)^T D_c R g = g^T P^T D_c^{-1} P g \rightarrow \text{max}$$

A convenient method for solving such a maximization problem with side constraints is the Lagrange multipliers technique

$$g^T P^T D_c^{-1} P g + \lambda (1 - g^T D_c g) \rightarrow \text{max} \Leftrightarrow P^T D_c^{-1} P g = \lambda D_c g$$

It is readily apparent from the previous equation that the original problem was reduced to an eigenvalue-eigenvector problem. To obtain the principal coordinates
for the column and row variables the singular value decomposition of the difference matrix $Q$ is now performed. By introducing the matrix $W$ to denote the result of the following similarity transformation of $Q$:

$$Q = P - xc^T, \quad W = D_x^{1/2}QD_x^{1/2}$$

the singular value decomposition yields (where $I$ is the identity matrix):

$$W = UD_\mu V^T, \quad U^TU = I, \quad V^TV = I$$

This is equivalent to (generalized singular value decomposition):

$$Q = U_iD_\mu^iV_i^T, \quad U_i^T D_\mu^i U_i = I, \quad V_i^T D_\mu^i V_i = I$$

The elements of the diagonal matrix $D_\mu$ are called principal inertias. A large value in $D_\mu$ indicates that the corresponding element has higher importance. With the above defined matrices the principal row and column coordinates are obtained as the appropriate entries of the matrices $F$ and $G$:

$$F = D_x^{-1}Q D_\mu^{-1} V_1 = D_x^{-1} U_1 D_\mu, \quad G = D_\mu^{-1}Q^T D_x^{-1} U_1 = D_\mu^{-1} V_1 D_\mu$$

The first one or two vectors of $F$ and $G$ are usually taken into consideration (one or two dimensions are displayed which have the highest contributions to the variance). Then, either the columns or the rows are plotted separately, or they are plotted simultaneously for constructing a biplot to find possible associations between the row and the column variables. Transitions between the columns and the rows might be done easily in the following way:

$$F = D_x^{-1} P G D_\mu^{-1} = R G D^{-1}_\mu, \quad G = D_\mu^{-1} P^T F D^{-1}_\mu = C F D^{-1}_\mu$$

These latter expressions can be used directly for the addition of supplementary rows and/or columns.

3 Exploring the Competency Profiles of Graduates

This research has focused on the recent process of education of the Budapest Tech as concerns the efficacy to its students to prepare them for the present and future challenges of the workplace. In the literature numerous surveys have been published for suggesting attributes, skills and motivation that are sought nowadays in the workforce market. These are termed competency profiles. There have appeared many studies addressing employer requirements of graduates, which reveal similarities and differences over time and across discipline boundaries, employment sectors and international boundaries. Among others, an excellent source on the Internet for these competencies which references to the OECD is
[9]. A document of the European Union provides profound details about the personal and professional competencies separately [10]. A comprehensive survey discussing the local situation was published in [4]. Obviously, however, there is no unique list of these competencies. At this point, with some alterations, author chose [11] as the best candidate and thus a reference of his research. This survey has several desirable features due to its complexity, global orientation and international acceptance. The competency profile of graduate employees is as follows (together with a suggested grouping):

**Group 1**

**Proficiency and Knowledge**
- A Adequacy of Knowledge in Appropriate Field
- B Ability to Apply Knowledge in Practice
- C Multi-disciplinary Perspective
- D Desire to Continue Learning
- E Capacity to Learn New Skills and Procedures
- F Capacity to Work with Minimum Supervision

**Group 2**

**Skills**
- G Communication Skills
- H Presentation Skills
- I Writing/Report Writing Skills
- J Capability to Present Well Reasoned Arguments
- K Analytical/Problem Solving Skills
- L Capacity for Co-operation and Teamwork
- M Capacity to Make Decisions
- N Management/Supervisory Skills
- O IT/Computing Skills

**Group 3**

**Abilities**
- P Ability to Access and Use Information
- Q Ability to Think Creatively
- R Adaptability/Resourcefulness
- S Capacity to Cope with/Manage Change

**Group 4**

**Globally Thinking**
- T Sensitivity to Different Viewpoints/Cultural Perspectives
- U International Awareness
- V International Experience
- W Capacity to function in Multicultural/Global Context
- X Capacity to Act Ethically
- Y Capacity to Act with Social Responsibility
- Z Capacity to Communicate in at least one Foreign Language

The main objective of an information gathering process among the recent students was to explore the degree to which the whole educational/teaching period has contributed to their achievements in the above attributes. To obtain reliable findings, it was required that the scope of the investigations is to be restricted to students who are attending in their fourth year of studies, i.e., who are just before
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graduation. This process was extended to potential opportunities provided by the school like laboratory facilities, libraries, learning languages, executive briefing sessions, internships, international exchange programs, etc. The progress in each of these attributes was measured on a seven-point scale (The use of such Likert-scales is common in applied research. They simply gauge the degree to which there is agreement or disagreement with statements to reflect clear positions on an issue and represent a desirable goal, namely a transition from ordinal scales to interval scales). The responders were asked to complete the survey forms, i.e. to rate each single item from 1 to 7 on these ascending scales, 26 attributes which employers expect graduates to demonstrate on entering employment. The verbal interpretation of the scale is enumerated below (the level of contribution to his/her development):

1 Not at all  
2 Very slight, on an unsatisfactory level  
3 Less than my expected minimum  
4 Minimum level I expected  
5 A little more than the minimum level I expected  
6 On a highly expected level  
7 Maximum level that can be expected

The survey was extended to the students of each faculty of the Budapest Tech (BMF). They are, with their codes:

Faculty of Mechanical Engineering = BGK  
Faculty of Electrical Engineering = KVK  
Faculty of Light Engineering = RKK  
Faculty of Informatics = NIK  
Faculty of Economics = KGK

The questionnaire forms have been exposed to severe inspections to filter them for possible non-sampling errors (data tabulating, coding, etc.). The size of the aggregated overall (total) sample and the sizes of the component samples were

TOTAL (403) = BGK (66) + KVK (100) + RKK (54) + NIK (93) + KGK (90).

Since the number of full-time students who are currently completing their studies at the BMF is approximately 1,500 and their proportions at the different faculties are well represented by the sample sizes both the overall and the component samples are representative samples (they conform to the stratified random sampling).

Now consider the overall sample (BMF) and carry out a statistical analysis by applying the correspondence analysis (CA) method. First the frequency of the responses (matrix \(N\)) is presented in the contingency table (Table 1).
Here, one may think of the 7-column values in each row of the table as coordinates in a 7-dimensional space. Computations of the (Euclidean) distances between the 26 row points would mean a rather tedious job in this 7-dimensional space. Therefore, we want to find a lower-dimensional space, in which to position the row/column points in a manner that retains all, or almost all of the information about the differences. A step-by-step analysis of this problem follows.
In terms of the Significance of Dependencies the value of the chi-square statistic is $\chi^2 = 640.466$, which is at $\alpha=0.05$, indicates a significant dependency between the rows (attributes) and the columns (contributions) ($p=0.000$). The next step concerns the Dimensionality of the Solution, i.e. to determine the appropriate number of dimensions to use in the solution. This requires the analysis of the singular values, percentages of inertia explained, the cumulative percentages and the contribution to the overall chi-square value. The dimensions are extracted so as to maximize the distances between the row or column points, and successive dimensions (which are orthogonal to each other) will explain less and less of the overall chi-square value. In our problem the first and the second axes account for 62% and 15.1% of the inertia, respectively, i.e. a cumulative total of 77.1%. This retention of the solution is high enough, as if the data were purely random with no significant dependencies, the average axis should account for $100/(7-1)=16.7\%$ of the inertia and $100/(26-1)=4\%$ in terms of the rows. Since the third axis accounts for only 12.8\% of the inertia, a 2-dimensional solution can be used. It may well occur that not all of the rows or columns are equally well represented. Determining the Quality of Representation of a particular row or column provides additional richness to the interpretation of the relationships in the contingency table. The quality of representation is evaluated by the sum of the squared correlations of that row and column over the $n$ dimensions. In our problem all categories and all competencies except $H=$Presentation skills ($I=0.047$) and $J=$Arguing ($I=0.106$) are well represented in the two dimensions (degree of association between a particular column and a particular axis.) This implies that some caution is needed when interpreting $H$ and $J$ in this space. As concerns the Compatibility of Row and Column Coordinates it is customary to summarize the row and column coordinates in a single plot. However, it is important to remember that in such plots, one can only interpret the distances between row points, and the distances between column points, but not the distances between row points and column points. Our concern in the current project lies with interpreting the meaning of the dimensions extracted in the low-dimensional solution, and in interpreting the placement of the competencies relative to those dimensions. We, therefore, utilized symmetrical normalization for the graphical representations.

The major result of our analysis is shown in Figure 1. This biplot is a perceptual map containing almost 80\% of the required information in two dimensions. In addition, as supplementary points, we displayed the faculty averages in the same plot to be able of making a subtle analysis of the results (a complex evaluation of the educational/teaching process at the Budapest Tech versus the expectations of employers of its graduates with respect to each competency as well as an analysis based on the comparisons of its five faculties). From this chart, it is apparent that according to representative bodies of students the educational/teaching process at the KGK conforms best to students’ expectations (its overall rating point is closest to the highest levels of achieved contributions) and the RKK performs as the least efficient faculty (its overall rating point locates farthest from the highest levels of achieved contributions).
In Table 2 we presented the weighted arithmetic means and the weighted standard deviations of each of the attributes for the aggregated assessments of the BMF and separately for the KGK. From this table it can be seen that the KGK evaluations outperform those of the BMF averages. Similarly, its student body is rather homogenous that is reflected by the much smaller dispersion of the scores. The deviations are positive and show quite significant differences from the BMF’s total mean scores. The overall weighted sample mean score for the BMF is $\bar{w}=4.10$, while for the KGK it yields $\bar{w}=4.65$. The weighted standard deviations are $\hat{s}=0.29$ and $\hat{s}=0.22$, respectively. The range of the weighted mean scores for the BMF is, $R=4.61–3.29=1.32$, whereas for the KGK, it is $R=5.0–4.0=1.0$.

As it is also shown in Table 2, a remarkable feature of the priority rankings generated from the competency ratings that they coincide fairly well for the entire school (BMF) and the KGK. The Spearman’s sample coefficient of rank correlation is $\rho=0.798$. Interestingly, on a higher level of measurement (on interval scale), for the magnitudes of the weighted mean scores the Pearson’s product moment sample coefficient of correlation is $r=0.777$. 

Figure 1
Symmetric biplot of the distances
Table 2

<table>
<thead>
<tr>
<th>Competency</th>
<th>BMFwm</th>
<th>KGKwm</th>
<th>RBMFwm</th>
<th>RKGKwm</th>
<th>BMFstd</th>
<th>KGKstd</th>
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<td>7</td>
<td>6</td>
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<tr>
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<td>6</td>
<td>2</td>
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<td>12</td>
<td>5</td>
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<td>8</td>
<td>9</td>
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<td>17</td>
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<tr>
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<td>4.62</td>
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<td>11</td>
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</table>

The bar chart of the weighted mean scores for the entire school is depicted in Figure 2 drawn in an ascending order. It is immediately seen from this exhibit that the ranked attributes according to the improvements in students’ developments follow very well the subsets of the single competencies. Thus, it can be stated, for example, that the largest contribution of BMF has been made in their abilities, in Group 3, since according to Figure 2 the leading elements (P,Q,R) belong to this group except L=Coop/Team which, otherwise, received the highest score from the student body. Its magnitude (4.61), nevertheless, (as well as those of the other competencies) deserves special attention from the senate of the BMF, since it represents the maximum and it just exceeds the minimum expectations of the students! Similarly, the attributes received the lowest scores also belong to a homogenous category, namely into Group 4 (Globally Thinking). BMF has to do a lot of efforts to achieve considerable improvements in these latter capabilities.
By reviewing the single (individually and independently completed) questionnaire forms, it turns out that the individual students cannot be divided into two major sets, say ‘under-motivated’ and ‘over-motivated’ subsets of students, since only a very small fraction of them have rated all competencies as the contribution of the BMF extremely low (1’s and 2’s), and, on the other hand, to be extremely high (7’s and some 6’s). Just the contrary, individuals have expressed their critical views with a healthy skepticism: they assigned to the attributes very high values for what they felt to be superior and they assigned to the attributes very low values for what they felt to be inferior. If the school wishes to make a deep analysis of the results of this survey, however, it must be taken into consideration that the students of the Budapest Tech arrive here with very different backgrounds in terms of basic academic knowledge, various skills and abilities, culture and personal attitudes, which makes difficult to draw general comments.

Conclusions

In this paper a competency profile of university/college graduates has been developed. These interrelated interactive attributes come together at one end of the adaptive-adaptable-transformative continuum to facilitate maximum value added by enabling people to fit in to the workplace culture. The performance of the Budapest Tech has been evaluated with respect to the achieved improvements of their students in these competencies based on their opinion. The research has shed a light to the fact that the level of satisfaction of the graduates is just a little bit above their minimum level of expectations. Correspondence analysis has proven a versatile and easily implemented tool in handling categorical data and in detecting and explaining relationships among these complex phenomena. Further investigations should reflect to the employers’ ratings of attributes expected of
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graduate employees as well as of actual graduate performance against attributes. These tasks, however, are subject to future research.

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