Digital Competency of the Students and Teachers in Ukraine: Measurement, Analysis, Development Prospects

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Abstract. Professional fulfilment of the personality at the conditions of digital economy requires the high level of digital competency. One of the ways to develop these competencies is education. However, to provide the implementation of digital education at the high level, the digital competency of the teachers and students is a must. This paper presents explanations on the level determination of the digital competencies for teachers and students in Ukraine according to the DigComp recommendations. We tried to identify the main factors that reflect the degree of readiness teachers and students for digital education based on their self-evaluation. Here we provide methodology and the model of level competencies determination by means of survey and the results of the statistical analysis. On the basis of the obtained results, this paper suggests further research prospects and recommendations on the digital competency development in educational institutions in Ukraine.

Keywords: Digital Competencies, Survey, Questionnaire, Principal Component Analysis, Education.

1 Introduction

Modern digital technologies are the catalyst for the world transformation [1]. Digital transformation has a huge impact on business and social life, providing the ways to unlock economic and social benefits. The Digital Economy (DE) Theme is supporting research to rapidly realise the transformational impact of digital technologies on aspects of community life, cultural experiences, future society, and the economy [2]. DE brings together a unique community of researchers from diverse disciplines, including social science, engineering, computer science, the arts and medical research; and users; including people, businesses and government; to study, understand and find solutions to real problems.

Most European countries approved development strategies until 2020. The Digital Agenda presented by the European Commission belongs to the seven main strategies and suggests wide usage of the Information and Communication Technologies (ICTs) potential in order to foster innovation, economic growth and progress [3]. Likewise, the Digital Agenda 2020 was approved in Ukraine [4]. The Digital Agenda must help to make maximum use of digital technologies [5], since the qualified professionals availability is crucial for creating a digital society and providing competitiveness of individual countries and their citizens [6]. However, as of 2017, according to the "digital skills" index of the European digital economy and society index (DESI), almost half (44%) of the EU population lacks skills in using digital technologies [7]. This, undoubtedly, is a large-scale problem that must be solved.

A number of researches [8] is devoted to the problem of reducing the gaps in digital competencies understanding by different categories of people. The EU recommendations on monitoring the Digital Economy & Society 2016-2021, suggest indicators for measuring digital skills [9]. Implementation of digital technologies influences many spheres and aspects of the society's activities, thus, for example, the possibility of employment, education, leisure, attraction and participation in society are transformed. The digital competence, as a confident use of information and communication technology (ICT) tools, is vital for a person to participate today's socio-economic life. That is why digital literacy (or digital competence) is recognized by the EU as one of the eight key competencies for a full life and activity. In this regard, the problem of improving (transforming) the education system as a social institution for human development for the training of competent specialists, taking into account the needs of the market and the current trends in the development of digital technologies, is being actualized.

This research aims to find if the subjects of the educational process in Ukraine are ready to use digital education as a tool, providing the digital competencies. The research concentrates only on studying the level of digital competencies of teachers and students, as on the factor that influences the quality of education.

2 System of the Digital Competency DigComp: Structure and Evaluation Model

There exist a few frameworks those allow to define the level of digital competencies. Among them there are European e-Competence Framework for ICT Professionals [10], European Computer Driving Licence [11], ICT Literacy Competencies, Global Media and Information Literacy Assessment Framework [12]. In our research we based on the European system of the digital competency, known also as DigComp, that provides general approach to defining and describing the main spheres of the digital competency of people and is the general mark in the European level [13]. DigComp agrees with other frameworks and has experience of implementation in European countries, for example, integration into the Europass CV system, which allows applicants to evaluate their own digital competence and to present the results of this assessment in CV [14].

The DigComp has three main directions: 1) policies formation and support; 2) training and employment programs planning; 3) evaluation and certification. In this paper the second direction is considered, in particular, readiness to implement open education [15]. In addition, digital competence DigComp refers to the necessary conditions for digital education implementation in The Digital Agenda 2020 Ukraine.

In 2017 EU suggested a new framework Digital Competence (DigComp 2.1) that has 5 dimensions [16]:

Dimension 1: Competence areas identified to be part of digital competence. There were defined areas: 1) information and data literacy; 2) communication and collaboration; 3) digital content creation; 4) safety; 5) problem solving.

Dimension 2: Competence descriptors and titles that are pertinent to each area. There were defined 21 competencies [16, p. 11].

Dimension 3: Proficiency levels for each competence. There are 4 main levels (foundation, intermediate, advanced and highly specialised) and their decompositions. Each level represents a step up in citizens' acquisition of the competence according to its cognitive challenge, the complexity of the tasks they can handle and their autonomy in completing the task [16, p. 13].

Dimension 4: Knowledge, skills and attitudes applicable to each competence [16, p. 19].

Dimension 5: Examples of use, on the applicability of the competence to different purposes. There were provided scenarios for two areas of use: employment and learning [16, p. 19- 20].

To evaluate the digital competencies on the base of DigComp framework, there were developed special methodologies and online tools [17]. To define the level of digital competencies the teachers and students of the educational institutions of Ukraine were suggested a list of questions. The authors developed a questionnaire containing 7 main sections according to recommendations of DigComp 2.1 (https://goo.gl/forms/h90Co24yF6vmU0JF2).

Sections 1-5 contain 21 questions that evaluate the level of digital competencies according to 5 areas of DigComp and consider the competencies usage in the field of education. The respondents were suggested a case: "You have to prepare a short report on the given subject and to provide it in the digital format". There were also a suggestion: "Use different tools and methods on every stage of process and communicate to different people (the examples below illustrate only some steps of work, as it doesn't refer to the subject). For each example write down how easy it was for you to do the task".

We suggest the next grading scale:

1. I am not sure I can perform this task on my own, I need some help (Foundation);
2. I can perform the task on my own, and I can solve the problems that appear during the work (Intermediate);
3. I can help others when performing the task, I can give some advice or help somebody to solve a problem (Advanced);
4. I can create a digital resource (a blog, a page in social networks, wiki, etc.) containing useful references, recommendations, instructions, and to provide help (lead a webinar, moderate the forum, etc.) (Highly specialized).

The model of tasks formulation and evaluation according to the DigComp recommendations is provided in the Fig.1.

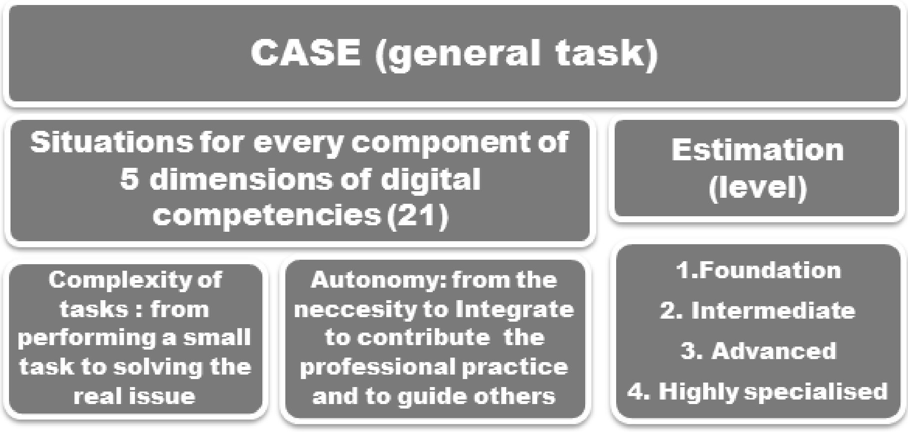

Fig. 1. The model of tasks formulation to evaluate the level of digital competencies (Source: Own work)

Section 6 contains 18 questions that must define online tools and information technologies that the respondents use to solve the tasks in sections 1-5. This section contains closed questions of multiple choice. Based on the given questions we found the validity of the respondents' answers and the frequency of usage of specific tools in the process of preparation of the report. The last section contains the questions that we need to fill in the personal profile of the respondent (considering the age, field of occupation, access level of IT, etc.).

3 Research Design

To study the problem of readiness of teachers and students for digital education and living in the digital world we chose the cross-section single research scheme.

Sample of the population was formed of employees, teachers and students of higher education of various fields: mathematics and informatics, humanitarian specialties, right and law, medicine and veterinary science, etc. The full list of the estimated features that reflect personal data of respondents is provided in table 1. Since the aim of our research wasn't exact assessment of competencies level in each field, but defining the communications between groups of the respondents those differ in age, gender sign, status (the student, the teacher), and field of occupation (technical or nontechnical), the error of representativeness didn't exceed 8% at total of the interviewed respondents (193 persons). The most of respondents are teachers and students of higher educational institutions as the National University of Life and Environmental Sciences of Ukraine, National Aerospace University "KHAI" and Boris Grinchenko Kyiv University. The questionnaire was widespread in two ways: on the Universities' webpages and through the social networks. Every feature has calculated beforehand descriptive statistics and constructed frequency distributions. The main features (characteristics of respondents) are provided in Table 1.

Table 1. The main characteristics of the respondents

Feature	Category of a feature	Meaning	Percent / Descriptive statistics
Gender	1	Male	25,10%
	2	Female	74,90%
Status	1	Teacher (Professor)	45,50%
	2	Student (Magister)	33,00%
	3	Student (Bachelor)	21,50%
Occupation	1	Education	26,20%
	2	Humanities and Arts	6,30%
	3	Business and Economy	0%
	4	Natural sciences (chemistry, biology, geography, etc.)	9,40%
	5	Mathematics, computer programming, IT	27%
	6	Health or veterinary medicine	1,60%
	7	Construction and architecture	0%
	8	Engineering (purely technical areas, including geodesy and transport)	6,30%
	9	Agriculture and agricultural machinery	4,20%
	10	Sphere of service, public administration, social security	2,10%
	11	Social sciences, law and jurisprudence	14,70%
	12	Others	3%
Availability of mobile and technical devices	1	Always	84,30%
	2	Not always	15%
	3	The availability is restricted, I can hardly use devices	0,50%
Availability of the websites on the educational books and article	1	Always	23,00%
	2	Not always	55,00%
	3	The availability is restricted as the full access requires money	22,00%
How did you improve your digital competency?	1	I improved my skills on my own	43,10%
	2	I got the basic skills at school	14,90%
	3	I improved my skills in university.	14,90%
	4	I participate online courses, webinars, communicate with my friends on the topic of IT	21,20%
	5	Other	5,90%
Age		Age of respondents	Mean=31,01 Median=23,5 Mode=22,0

The main tasks of the research were:

- to describe of the level of digital competencies by fields of occupation;
- to estimate the numbers on usage of available digital applications, comparison of the level values for different groups of respondents, strength of the connection between the various characteristics evaluation;

– to study of the cause-effect dependencies of the competence level and the properties of the respondents.

One of the tasks was to evaluate the validity and reliability of the assessment tool, i.e. developed questionnaire. We also needed to highlight the main components of digital competencies, which had significant differences for different groups of respondents. These hypotheses were formulated:
1. The average level of digital competencies among the majority of respondents is above the average for the entire sample.
2. The levels of competence in the competence of digital data processing, online communications and protection, transmission and storage of information depend on the gender, status, training directions, accessibility of technical and mobile means and the way knowledge and skills are acquired.
3. The respondents who master basic digital competencies can simply solve other problems related to the use of digital tools.

3.1 The Description of the Variables

We determine variables, scale of evaluation and interval for the questions in our questionnaire (Table 2).

Table 2. The questionnaire specification

Groups of questions	Variables	Indication of the variable of points	Scale of evaluation	Intervals of evaluation
Processing data	V11-V13	V1	Ordinal	1..4
Communication	V21-V26	V2	Ordinal	1..4
Creation of digital content	V31-V33	V3	Ordinal	1..4
Information security	V41- V43	V4	Ordinal	1..4
Solving technical problems	V5	V5	Ordinal	1..4
Studying and data analysis	V61- V62	V6	Ordinal	1..4
Personal data	P1-P6, P8	-	Nominal	Categories depending on a variable (Tab. 1)
Questions to evaluate the usage of digital competency tools	I11-I13 I21-I26 I31-I33 I41-I43 I5 I61-I62	-	Nominal, Multiple Response	1..8

3.2 The Methods and Models of Data Processing

When analyzing we used a complex of methods and models that allow to calculate all the descriptive statistics. The choice of certain indicators is influenced by the data type, the scale of assessment and the limitations of methods application. For calculations, we used the software tool for statistical processing data SPSS [18, 19].

Most of the features chosen to assess the level of digital competencies in the survey process were estimated in an ordinal 4-point scale. Therefore, in order to test the hypotheses, the method of analyzing two-dimensional frequency tables (contingency table) and the chi-square test was used at the first stage [18]. Also, the Cramer's V, contingency coefficient and the coefficient Phi, which are called measures of association, were calculated. These coefficients vary from 0 to 1 and allow us to conclude about the strength of the relationship between the features.

One of the analysis purposes is to estimate reliability of the questionnaire [20]. To estimate of internal consistency of single questions of the questionnaire the coefficient Cronbach's alpha was used. Besides, for respondents questions which purpose was to confirm level of proficiency in these or those competences have been offered. Such questions, as a rule, contains answers concerning the tools used for the solution of the tasks within digital competences. For a research of the communications between the main points of the questionnaire and questions concerning tools methods of the analysis of two-dimensional frequency tables have also been used.

A number of features did not allow us to draw single-digit conclusions on the general tendencies of different groups of respondents' digital competences possession. Therefore when data processing methods of data reduction were used. The first approach was based on estimation of the total (aggregated) ball score on the groups displaying the main directions of digital competences. In Table 2 you can see the main groups on which score was calculated. For the analysis of distinctions of average summary points the method of one-factor dispersion analysis (ANOVA) was used further [21]. The second approach was based on a method of the principal components [22] that allows transforming without loss of data to such variables which values cause the maximum value of variance of the initial features. The further analysis of communication of factor values with groups of respondents was carried out on the basis of the frequency tables using methods of graphic visualization of data.

When testing statistical hypotheses at all analysis stages the decision is made on the basis of the size p-value which actually displays probability of a mistake at a deviation of a zero hypothesis (an error of the first type). The p-value for a deviation of a zero hypothesis was accepted equal 0,05.

4 Results of Research

At the first stage, we provided frequency distributions of the respondents' scores for each question and on the total values. Figure 2 shows the distribution histograms by groups of digital competencies.

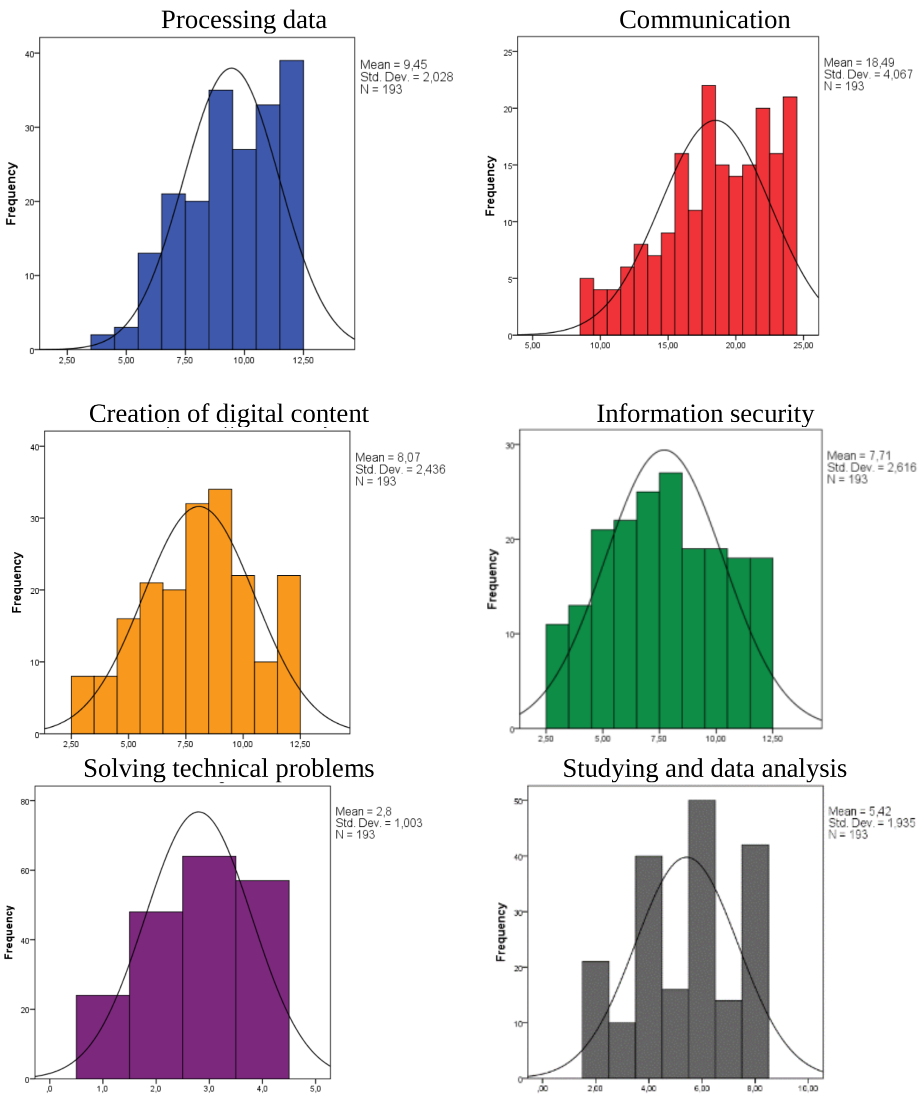

Fig. 2. Diagrams of the scores distributions according to the fields of digital competencies (Source: Own work)

From Figure 2, we see that for most of the competencies, respondents rated their abilities above average. At the same time, the significance of the differences was confirmed by the value of the Student's t-test at the level $p < 0{,}05$. Thus, we can accept the hypothesis that the level of digital media and communications usage among teachers and students is quite high and above the average.

The analysis of two-dimensional frequency tables (cross tabulations), and the criteria on the basis of which it is possible to assess whether there is connection between such characteristics as the assessment of the level of one's own competencies and status, gender, and occupation proved that for most of the features of communication it is not observed for p> 0,05.

The coefficients of Cramer's V and contingency ranged from 0,086 to 0,366, that indicates weak connection between the traits. Therefore, the study focused on the analysis of total scores by groups of competencies. Table 3 provides the values of the significance criteria for the differences in the total ball-point estimates for the main areas of digital competencies among the groups of respondents. The table shows the F statistics and p-value calculated using the ANOVA method.

Table 3. Criteria of value of scores on different fields of digital competencies among the groups of respondents

Measuring digital competences directions	Gender		Status		Occupation		Availability of mobile and technical devices		Availability of the websites on the educational books and article	
	F	p-value	F	p-value	F	p-value	F	p-value	F	p-value
Processing data	2,11	0,15	9,59	**0,00**	2,14	**0,03**	0,44	0,65	6,23	**0,00**
Communication	0,06	0,81	1,25	0,29	1,38	0,20	0,46	0,63	6,61	**0,00**
Digital content creation	3,24	0,07	1,46	0,23	3,31	**0,001**	1,9	0,15	5,96	**0,00**
Information security	2,82	0,10	0,43	0,65	2,44	**0,01**	0,72	0,49	10,29	**0,00**
Solutions of technical problems	5,51	**0,02**	0,29	0,75	1,47	0,16	1,39	0,25	8,25	**0,00**
Studying and analysis of data	1,92	0,17	4,04	**0,02**	1,54	0,14	1,74	0,18	7,20	**0,00**

We can see significant differences in evaluation of their competencies occur among teachers and students, among the respondents of different occupations, and among those who has limited access to websites with scientific books and articles (significance level was considered for p < 0,05). The difference among the groups was also tested by the criterion of Tukey: the greatest differences were revealed between students and teachers. The teachers' scores are significantly higher. The level of competence among those whose occupations are related to mathematics, computer science and information technology differs from the rest of the groups. The respondents with limited access or no access to websites with special literature have the levels of digital competencies significantly lower than those who have permanent access.

We analyzed the relation between the question "How to obtain digital competency?" and the final scores in the fields of digital competencies estimating. Since the question was presented on a scale with compatible alternatives, we perform the analysis on the basis of a two-dimensional frequency table. The analysis proved the level of competencies does not depend on the way knowledge and skills were obtained.

To analyze the relationship between age and total scores we used a linear regression model. The results showed a lack of connection between the features. The coefficient of determination (R squared), which shows the tightness of the connection, was 0.042, and the coefficient of linear correlation (Pearson's r) was 0.206, which indicates the absence of a linear relationship between the signs.

Thus, the hypothesis that the level of competences depend on gender, status, activities and access to digital media, the way of teaching was partially confirmed.

In the framework of the questionnaire analysis reliability, we prepared the contingency table between the features, those reflect the respondents' assessment of their digital competencies and the tools used. Analysis of these tables proved that the higher is the respondent's self-esteem the more tools he owns and uses in his daily practice. The indicators reflecting the internal consistency of the questionnaire were also evaluated, namely, the Cronbach alpha was 0.944, Lambda Guttmann 0.89, the Spearman-Brown coefficient 0.889, and the intra-group correlation coefficient 0.49. These numbers indicate the questionnaire high reliability.

To reduce the data, we used the principal component analysis (PCA), which was based on 18 features with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin measure confirmed the adequacy of the sample for analysis, KMO = 0.939 ("excellent" in [18]), and all KMO values for individual traits were greater than 0.914, well exceeding the permissible limit of 0.5 [18]. Bartlett's test of sphericity χ^2 (153) = 2251,953, with p <0.0001, proved that the correlations between the points were quite large for PCA. The initial analysis was performed to obtain the eigenvalues for each component in the data. Two components had similar values according to the Kaiser's criteria of 1 and higher, and in combination they explained 60.01% of the variance. The scree plot showed inflexions that would justify retaining two components (Fig. 3). Given not large sample, and the convergence of the scree plot and Kaiser's criterion on two components, this is the number of components that were retained in the final analysis.

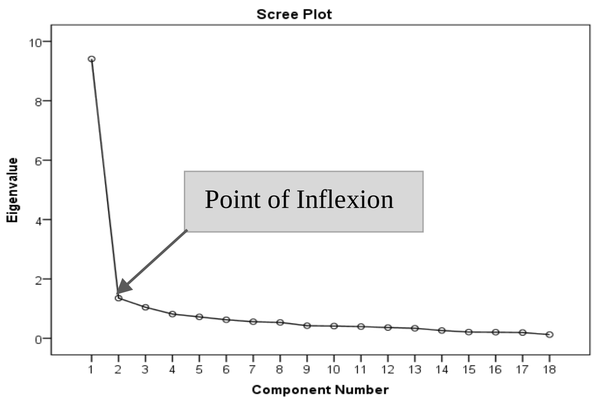

Fig. 3. The scree plot graphs the eigenvalue against the component number how many components we have to retain (Source: Own work)

Table 4 shows the load factors after rotation. The attributes are added to the main components by the absolute values of the coefficients of the rotated matrix (the cells are highlighted in color). Some characteristics can be attributed to both components (they are reflected at the bottom of the table), but they were assigned to the second component. The elements that are grouped on the same components assume that principal component 1 (PC1) is a digital competency, as a means of use and communication, component 2 (PC2) - the competence of the professional use of information tools.

Table 4. Summary of exploratory factor analysis results for the digital competence questionnaire (N = 193)

Rotated Component Matrix		
	Component	
	PC 1 - digital competencies as mean of communication	PC 2 - competencies of professional usage digital resources
Preparation of the report	0,72	0,24
Search for sources of information	0,77	0,07
Information storing	0,76	0,35
Choice of communication tools	0,45	0,58
Use of mail and cloud services	0,59	0,43
Informing the public	0,66	0,49
Tools for joint activities	0,61	0,42
Netiquette rules following	0,55	0,34
Account management, creating accounts	0,64	0,44
Creation of animated presentations	0,64	0,37
Copyrights	0,70	0,24
Developing simple applications for websites or smartphones	0,24	0,67
Identification of risks when accessing dialers or digital platforms	0,16	0,87
The choice of the optimal protection means	0,32	0,80
Awareness risks	0,31	0,73
Technical tasks solutions	0,32	0,73
Ability to visualize data	0,55	0,54
Online Learning usage	0,55	0,59
Eigenvalues	9,499	1,304
% of variance	52,77	7,242
Rotated loadings	0,727	0,686

In Figure 4, you can see the graph of the analysis result of the main components method with the eigenvectors selected. We can say from the graph, that the initial correlation of characteristics separates the initial data no more than in two directions, which led to the selection of the two main components. At the same time, one can find it difficult to single out separate groups of attributes for some components. This suggests that the various digital competencies are closely related.

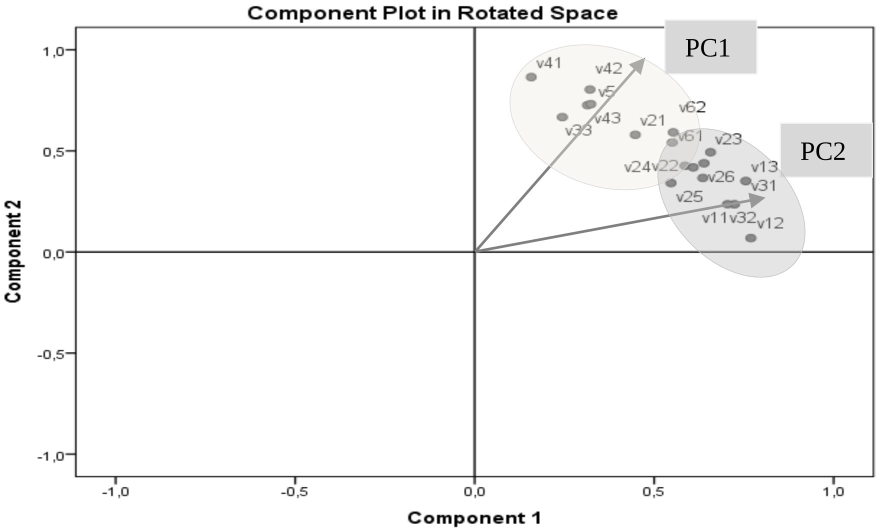

Fig. 4. The graph of the contribution of characteristic values to the main components

The further analysis of the obtained factor values on the basis of the method of principal components in the context of the groups of respondents (by sex, status, activities, availability of digital means) did not show significant differences in gender and availability of technical means. Teachers have a significantly higher level of factor values for the first component, while students have better competencies in the second component ($p<0,05$). There are also significant differences between groups of respondents working or studying in different areas of activity. Significantly higher average factor values of the first component in the groups of humanitarian and healthcare respondents, while the second component identifies respondents whose activities are related to mathematics, information technology and information technology, as well as engineering direction ($p<0,05$). Those who have access to resources with scientific literature have higher averages for both components compared to groups of respondents whose access is limited.

Thus, it can be concluded that respondents who know the basic digital competencies solve equally other problems related to the use of digital tools. However, there are some differences in the level of digital competencies between users of information resources solely for solving the problems of searching, presenting, storing and transmitting information, and respondents able to solve technical problems, providing reliable protection and processing of data by means of special means. Most people learn skills independently, regardless of the direction of activity, status and access to technical and digital tools.

5 Conclusions

The digital competencies are essential for people to achieve success at the condition of the digital economy. The results of a survey in which participated 193 teachers and students of Ukrainian educational institutions aiming to define the readiness to implement digital education for obtaining the digital competencies allow us to conclude:

1. The teachers and students have the above average level of usage of digital tools and communications. However, the level of competencies does not depend on the way that the skills were obtained.

2. The level of competency of professional usage of IT is much higher for students than for teachers. The teachers have higher level of IT usage for performing educational tasks. The level of competencies in exact sciences differs from the others. The level of competencies of the respondents who has restricted access (or no access at all) to the resources with the literature is far lower, than the level of those respondents who has full access to such resources.

3. There were defined no difference on gender, age and availability of technical means.

Since the analysis of the obtained data confirms high reliability of the questionnaire developed by authors, we can formulate the further researches perspectives. It seems to be perspective to measure the digital competencies in each field of DigComp and to develop the training modules for formal or informal training.

The sufficient level of digital competencies of both students and teachers proves their readiness for digital training implementations. The difference of levels of students (as the developers of e-content), and teachers (as the competent users), can be used efficiently to provide collaborative training online.

Consider that digital competencies influence the training programs structure, professional development of teachers and services and resources intended for students at the university. That is why there must be created uniform environment of digital competencies management at the university. That allows providing within the university: common information space for control, development and a transfer of digital competencies; optimized communication between students, teachers and administration of the university; individual planning, monitoring and management of educational trajectory personally for every student.

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