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The Construction and Application of E-Learning Curricula Evaluation Metrics for Competency-Based Teacher Professional Development

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Abstract: Today, students at universities in advanced countries typically enroll in colleges, such as the College of Education, which offer interdisciplinary programs for undergraduates in their first and second years, allowing them to explore personal interests, experience educational research fields, complete their integrated curricula, and then choose a major in their third year. To cooperate with the government's epidemic prevention policies and measures in the post-COVID-19 era, the trend of e-learning and distance teaching has accelerated the establishment of integrated online curricula with interdisciplinary programs for undergraduates in the College of Education to facilitate effective future teacher professional development (TPD). Therefore, it is very important to construct e-learning curricula evaluation metrics for competency-based teacher professional development (CB-TPD) and to implement them in teaching practice. This research used social network analysis (SNA) methods, approaches, and theoretical concepts, such as affiliation networks and bipartite graphs comprised of educational occupational titles and common professional competencies (i.e., Element Name and ID), as well as knowledge, skills, abilities, and other characteristics (KSAOs), from the U.S. occupational information network (O*NET) 26.1 OnLine database, to collect data on the occupations of educational professionals. This study also used Gephi network analysis and visualization software to carry out descriptive statistics of keyword co-occurrences to measure their centrality metrics, including weighted degree centrality, degree centrality, betweenness centrality, and closeness centrality, and to verify their importance and ranking in professional competency in eight categories of educational professionals (i.e., three categories of special education teachers and five categories of teachers, except special education). The analysis of the centrality metrics identified the educational common professional competency (ECPC) keyword co-occurrences, which were then used to design, develop, and apply e-learning curricula evaluation metrics for CB-TPD. The results of this study can be used as a reference for conducting related academic research and cultivating educational professionals' online curricula, including ECPC keywords, integrated curricula design and the development of transdisciplinary programs, and teacher education, as well as to facilitate the construction and application of future e-learning curricula evaluation metrics for CB-TPD.

Keywords: competency-based teacher professional development; educational common professional competency; keyword co-occurrence network; social network analysis; e-learning curricula evaluation metrics; centrality metrics

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1. Introduction

The current research used the U.S. occupational information network (O*NET) 26.1 OnLine database [1] to search for the occupational summary reports of educational professionals, including "special education teachers" and "teachers, except special education". Complete data were retrieved in eight categories of educational professionals (i.e., preschool, kindergarten, elementary school, middle school, and secondary school teachers, except special education, and preschool, middle school, and secondary school special education teachers; however, there were no complete data for kindergarten and elementary school special education teachers, and thus the incomplete data were not included in the scope of the research analysis). The eight categories of educational professionals' occupational summary reports were searched using the attributes of knowledge, skills, abilities, and other characteristics (KSAOs) from the O*NET database to find existing keywords related to educational common professional competency (ECPC) [2,3].

Higher education in today's advanced countries is typically based on college enrollment rather than department enrollment. For example, the transdisciplinary program in the College of Education has created a platform for students to explore their interests, complete their integrated curricula during their first two undergraduate years, and facilitate choosing a major aligned with their interests and aptitudes in their third year, accordingly. Moreover, this program aims to break boundaries of individual disciplines to integrate interdisciplinary knowledge and technology. Through a well-organized scheme, students can better understand not only their departments but themselves, explore personal interests, experience educational research fields, and choose majors for occupational specialization [4]. This interdisciplinary/transdisciplinary education curriculum design and implementation has become a trend in higher education [5], and this educational model combining disciplines and interdisciplinary/transdisciplinary fields also exists in the Qualifications Frameworks in the European Higher Education Area [6].

To cope with the government's epidemic prevention measures in the post-COVID-19 epidemic era, the new trend of distance digital teaching in e-learning has led to the establishment of integrated e-learning curricula in all departments of the College of Education. This integrated e-learning curricula design across education majors has created a blended learning system, combining e-learning technology with traditional educator-led teaching [7], which includes ECPC keywords and practical curricula content of different educational professionals as reported in the O*NET database [8]. The integrated e-learning curricula for competency-based teacher professional development (CB-TPD) can be applied to TPD curricula at different stages, such as teacher education curricula for in-school intern teachers (i.e., student teachers), graduate intern teachers, and in-service teachers [9]. This blended learning system will also contribute to the effectiveness of TPD in the future.

O*NET adopted its original investigation framework from competency-based concepts to survey and measure competency in TPD, including the KSAOs needed to perform job tasks. The metadata from O*NET used in longitudinal studies are suitable for the design and development of e-learning curricula for CB-TPD. Consequently, it is very important to construct e-learning curricula evaluation metrics for CB-TPD and apply them to teaching practice.

During the COVID-19 pandemic, investing in sufficient educational resources to enhance the development of e-learning curricula improved time management and reduced teachers' work–home conflicts and teaching pressure [10,11]. Evaluation metrics for CB-TPD are necessary to create e-learning curricula for education for sustainable development (ESD) and preservice education programs for student teachers, intern teachers, and in-service teachers. Evaluation metrics can also establish the effectiveness of e-learning curricula, define the competency-based transformation processes initiated by participation in TPD experiences, and induce positive effects in TPD [12]. Therefore, the aim of this research was to develop e-learning curricula and construct evaluation metrics for CB-TPD to verify the importance of the evaluation of the curricula.

In general, this study is different from the quantitative analysis methods that generally collect data by questionnaires, such as structural equation modelling (SEM) and analytic hierarchy process (AHP). The research results are usually accompanied by the errors and biases of the SEM questionnaire surveys, or the AHP method can be used to identify the importance of influence factors to maintain a questionnaire response's consistency, but this research uses the real data of the occupational summary reports and metadata of eight categories of teachers by the O*NET database to conduct complex network centrality analysis to construct the e-learning curricula evaluation metrics for CB-TPD, presenting the visualization of the centrality metrics in the research results. In this study, the research methods and design used can make up for the research limitations and gaps in constructing the e-learning curricula evaluation metrics with research methods such as SEM and AHP.

2. Literature Review

Referring to past research, metadata from the O*NET database were used to develop quantitative assessment scales, information technology, and algorithms, such as the prediction and construction of an evaluation system, to conduct research on teachers' professional competencies [2,13–15]. This research used social network analysis (SNA) methods, approaches, and theoretical concepts, such as affiliation networks and bipartite graphs [16] that included occupational titles, Element Name and ID, and KSAOs [17] from the O*NET database, to design and implement CB-TPD curricula, as shown in Figure 1. In addition, ECPC keyword co-occurrences were analyzed by centrality metrics to construct e-learning curricula evaluation metrics for CB-TPD and verify their importance [18].

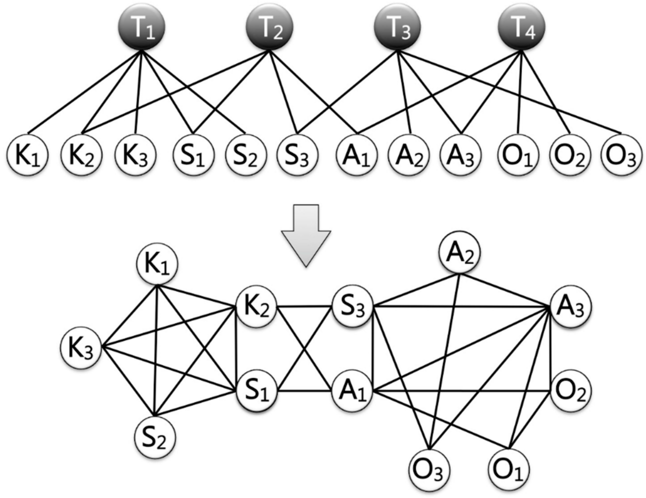

Figure 1. The construction of the affiliation network and bipartite graph.

The bipartite network in Figure 1 shows vertices K_1 to K_3, S_1 to S_3, A_1 to A_3, and O_1 to O_3, which represent the attributes of the KSAOs, and vertices T_1 to T_4, which are the occupational titles of the teachers, and the lines between them connect the attributes of the KSAOs to the corresponding occupational titles. The lower half of the figure displays the unipartite projection of the bipartite network in the upper half of the figure, showing that two KSAOs are connected if they simultaneously exist with the occupational titles.

2.1. Competency-Based Education and Competency-Based Teacher Professional Development

Recent research has revealed a model of technological practice-based learning that was constructed in a smart and efficient interaction environment of e-learning curricula, with case-based learning and simulators for competency development [19]. At the present stage, many universities developing competency-based education (CBE) programs and learning models in higher education for students and teachers are filling the gap between academic outcomes and industrial needs [20], and current techniques and contents of CBE can be used for the curricular design of faculty development programs for continuing professional development [21], especially for TPD. Quantitative analysis methods to assess the outcomes of CBE programs have identified the continuity of learning outcomes [22]. Studies on e-learning in CBE, particularly those exploring mobile learning elements such as students, teachers, content, learning designs, learning activities, learning environment, technology, and assessment based on CBE in technical and vocational education training fields [23], have found that these elements are very important to evaluate e-learning curricula for CB-TPD.

2.2. Social Network Analysis and Centrality Metrics

Centrality represents the position and function of each network node and its central location, including weighted degree centrality (C_{WD}), degree centrality (C_D), betweenness centrality (C_B), and closeness centrality (C_C). Based on previous studies, the centrality metrics of SNA can validly measure the position and function of nodes in a complex network, which can assist researchers in understanding the importance of the roles played by individual nodes in the associated network [24]. Thus, the current study adopted a mixed-method approach that included bibliometric analysis and SNA to construct a keyword co-occurrence network (KCN) [25,26]. Then, Gephi network analysis tools were used to conduct centrality analysis for the visualization of the network matrix to present a complex network map [25,27]. Centrality quantifies and evaluates the importance or influence of a specific object (node or edge) within a network [25,26,28], the analytic application of which has been presented in recent research. SNA and centrality metrics can be used to obtain quantitative evidence of learning acquisition outcomes in CBE, as measured by the evaluation of curricula in universities, which can be applied to collaborative learning methods, such as group work in the classroom, to achieve professional skills [29].

3. Research Method

The research framework and procedures used in this study entailed six steps, as shown in Figure 2. The first step was to collect data from the O*NET database, such as teachers' occupational titles, Element Name and ID (data were collected if its importance scale value was $\geq$3.0), and the attributes of the KSAOs. The second step was to extract keyword co-occurrences from the eight categories of educational professionals' occupational titles, including "Special Education Teachers, Preschool", "Special Education Teachers, Middle School", "Special Education Teachers, Secondary School", "Preschool Teachers, Except Special Education", "Kindergarten Teachers, Except Special Education", "Elementary School Teachers, Except Special Education", "Middle School Teachers, Except Special and Career/Technical Education", and "Secondary School Teachers, Except Special and Career/Technical Education", as well as occupational summary reports and metadata, from O*NET OnLine. The third step was to construct a KCN using the teachers' occupational titles and Element Name and ID as nodes. The fourth step was to conduct SNA by calculating the centrality metrics of C_{WD}, C_D, C_B, and C_C, and then the fifth step was to present the ECPC keyword co-occurrences in visualization graphs. The sixth and final step was to provide the results of the SNA and discuss the comparisons between the centrality metrics and the ECPC keyword co-occurrences in the visualization graphs.

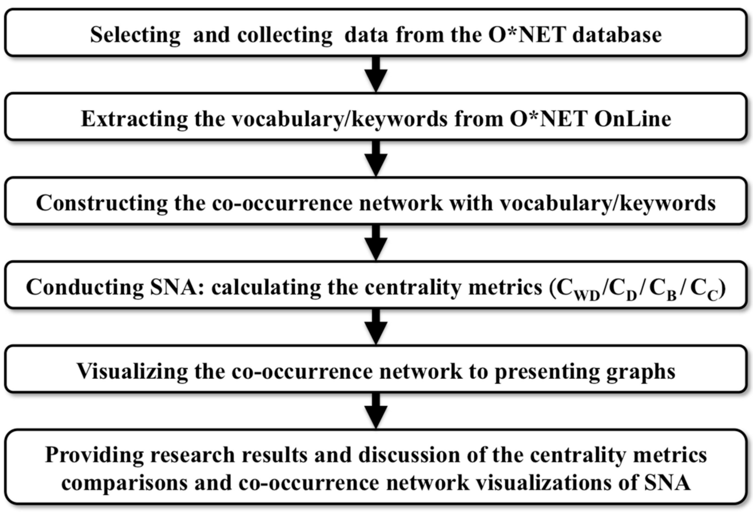

Figure 2. Research framework and procedures.

3.1. Data Sources

The O*NET database of job characteristics contains a rich set of variables that describe work and worker characteristics, including skill requirements, data on abilities required for the occupation as rated by experts who were identified through professional organizations and educational institutions related to the occupation, and all data surveyed in the U.S. economy and all industries [15]. Researchers, developers, and other users are encouraged to incorporate the O*NET database in their researches, products, and services. The extracted data of the current research, such as the real data content of the attributes of the KSAOs, were collected from O*NET OnLine, and more details on data collection and occupational summary reports are described by the O*NET OnLine/O*NET Resource Center [1].

The occupational summary reports and metadata of eight categories of teachers according to the attributes of the KSAOs in the O*NET database [1–3] were used to find existing ECPC keywords related to teachers, except special education (preschool, kindergarten, elementary school, middle school, and secondary school) and special education teachers (preschool, middle school, and secondary school). The educational professionals' occupations (including main categories, O*NET Standard Occupational Classification [O*NET-SOC] codes, and occupational titles); the individual network of ECPC; the individual merged network of ECPC; and all the statistics for nodes, edges, and density in the respective networks are presented in Table 1.

Table 1. Educational professionals' occupations, ECPC networks, and corresponding statistics.

Educational Professionals' Occupations				**Individual Network of ECPC**				**Individual Merged Network of ECPC**			
Main Category	**O*NET-SOC Code**		**Occupational Title**	**Node**	**Edge**	**#Edge**	**Density**	**Node**	**Edge**	**#Edge**	**Density**
Special Education	★	25-2051.00	Special Education Teachers, Preschool	143	142	152	0.014	195	457	491	0.024
	•	25-2055.00	Special Education Teachers, Kindergarten	•	•	•	•				
	•	25-2056.00	Special Education Teachers, Elementary School	•	•	•	•				
		25-2057.00	Special Education Teachers, Middle School	155	154	168	0.013				
		25-2058.00	Special Education Teachers, Secondary School	162	161	171	0.012				
Except Special Education		25-2011.00	Preschool Teachers, Except Special Education	104	103	113	0.019	179	629	685	0.039
		25-2012.00	Kindergarten Teachers, Except Special Education	121	120	122	0.017				
	★	25-2021.00	Elementary School Teachers, Except Special Education	135	134	150	0.015				
		25-2022.00	Middle School Teachers, Except Special and Career/Technical Education	141	140	158	0.014				
		25-2031.00	Secondary School Teachers, Except Special and Career/Technical Education	133	132	142	0.015				
The Complete Network of ECPC (Merged The Special Education And The Except Special Education)				Total Node		Total Edge		Total #Edge		Density	
				222		1086		1176		0.044	

Note: The O*NET-Standard Occupational Classification (SOC) system is used by federal statistical agencies to classify workers and jobs into occupational categories for the purpose of collecting, calculating, analyzing, or disseminating data; the number of nodes and edges (associations) listed above have been deducted with the number of duplicate nodes and edges; "★": Bright Outlook occupations are expected to grow rapidly in the next several years, will have large numbers of job openings, or are new and emerging occupations; "•": this title represents an occupation for which data collection is currently underway; "Total Edge": the number of edge types; "Total #Edge": the sum of existing edges.

3.2. Centrality Metrics of the Social Network Analysis

The centrality metrics of the SNA included C_{WD}, C_D, C_B, and C_C. C_D measured the number of node edges, defined as the number of participants (i.e., interactive nodes) a focal participant (i.e., measured node) interacted with, while C_C was defined as a focal participant's distance from all other network participants; thus, C_D and C_C were highly correlated with each other [30,31]. C_C also measured a focal participant's distance relative to all other participants in the network. Furthermore, C_B measured the extent of an individual node serving as a mediator between two participants with the shortest paths [32,33]. In measuring the C_{WD} and C_D values, if $C_{WD} = C_D$, no overlapping edges existed between the nodes; on the contrary, if $C_{WD} > C_D$, overlapping edges existed between the nodes and they needed to be weighted [34–39]. Referring to previous research, the definitions of the centrality metrics and the characteristics of their central nodes [30,31,34–40] are summarized in Table 2.

Table 2. Definitions of centrality metrics and characteristics of their central nodes.

Centrality Name	Definition of Centrality	Characteristics of a Central Node
Weighted degree centrality (C_{WD})	Consists of the degree of a node and the degree of its neighborhoods, and holds the advantages of local information and wider application in weighted network [38]	A node is used to characterize its overall connectivity to other sequences in the network [39]
Degree centrality (C_D)	The number of participants (interactive nodes) a focal participant (measured node) interacts with [30] The degree centrality is determined by the number of edges associated with the nodes [34] The degree centrality is a measure of the influence of a node about its direct neighbors [35] The degree centrality is the number of lines directly connected with a node [37] The number of edges incident to a certain node [40]	Connected to many other nodes [31] Emphasis on the degree of direct connection with other points (nodes) [36] Indicating the degree to which the node is close to the center of the entire network [37] Nodes with a high degree (more connections with others) are more likely to have access to information and influence others' decisions [40]
Betweenness centrality (C_B)	Could be measured to evaluate the extent of the individual serving, such as a mediator between two participants with the shortest paths [30] Betweenness centrality identifies nodes that will be intermediaries for information [34] Betweenness centrality shows informal power to connect two nodes, and it can influence their relationships [35] Betweenness centrality is the ratio of the number of shortcuts connecting two nodes through a third node to the total number of shortcuts between these two nodes [37] The number of other vertices that must pass through a specific node to reach their shortest path [40]	Lies on many shortest topological paths linking other node pairs [31] Emphasis on the degree of being in the middle of any other two points (nodes) [36] Representing the ability of this node to control other nodes [37] Nodes with high betweenness centrality act as 'pivot points of knowledge flow in the network', while they connect different nodes together and usually have multidisciplinary knowledge [40]
Closeness centrality (C_C)	A focal participant's (measured node's) distance to all other network participants (interactive nodes) in the network [30] Closeness centrality is the average distance from a given node to all other nodes in the social network [34] Closeness centrality helps a node to spread information rapidly [35] Closeness centrality is the sum of the shortcut distances between a node and all other nodes in the overall network [37] The sum of the geodesic paths between a node and every other node in the network [40]	Low average shortest path length to other nodes in the network [31] Emphasis on the minimum distances from all other points (nodes) [36] Representing the proximity between the node and other nodes in the network [37] Closeness centrality represents the ease of passing/accessing information between nodes; therefore, nodes with high closeness can have faster and easier access to/spread of information and communication with others [40]

The individual and network levels of SNA used to research e-learning curricula designs and community interaction in past studies [30] were combined into a hybrid level of SNA in the current research. The individual-level SNA results provided insights into how the learners' roles in TPD and the instructors' roles in developing e-learning curricula for CB-TPD changed with the implementation of CB-TPD pedagogy over time. The network-level SNA results delineated the state of the e-learning community and the development of the e-learning curricula for CB-TPD used in the implementation of CB-TPD pedagogy.

4. Results

4.1. Data Processing

In this study, first, Excel software was used to collect data from the eight categories of educational professionals' occupational summary reports in the O*NET database with the aid of the attributes of the KSAOs to find ECPC keyword co-occurrences in the merged network of special education teachers and teachers, except special education. Second, the ECPC keyword co-occurrences were stored in a .CSV text file. Third, the Gephi software algorithm "Force Atlas2", a continuous graph layout algorithm that showed the visualization of the ECPC KCN related to the e-learning curricula evaluation metrics for CB-TPD, was used to analyze the centrality metrics of C_{WD}, C_D, C_B, and C_C.

4.2. Centrality Analysis of Educational Common Professional Competency

In the current study, the centrality metrics analyses of ECPC directly related to designing, developing, and implementing e-learning curricula for CB-TPD were performed using the attributes of the KSAOs. The numerical values of the centrality metrics were ranked for comparison [40] in descending order, with the highest numerical values listed at the top.

4.2.1. Centrality Analysis of the Knowledge Characteristic

The centrality metrics for the knowledge (K) characteristic are reported in Table 3, and the histogram is shown in Figure 3. While $C_{WD} = C_D$ indicated that no overlapping edges existed between the nodes, the numerical values of C_{WD}, C_D, C_B, and C_C for four ECPC keywords in the O*NET database—Customer and Personal Service, Psychology, Education and Training, and English Language—were all equal regarding ranking and importance. The numerical values of C_{WD} and C_D for both Public Safety and Security and Computers and Electronics were the same, but for Public Safety and Security, the numerical values of C_B and C_C were greater than those for Computers and Electronics, so Public Safety and Security had a higher ranking than Computers and Electronics. Moreover, for Sociology and Anthropology, the numerical values of C_{WD} and C_D were less than those for Clerical and Mathematics for K, while the numerical values of C_B and C_C were greater than those for Mathematics and less than those for Clerical for K, and the different centrality rankings represented differences in the importance of the different nodes.

Table 3. Keyword numerical values of the centrality metrics for the knowledge characteristic.

ECPC of O*NET-SOC		C_{WD}	C_D	C_B	C_C
2.C.1.e	Customer and Personal Service	8	8	33.0200	0.5092
2.C.4.e	Psychology	8	8	33.0200	0.5092
2.C.6	Education and Training	8	8	33.0200	0.5092
2.C.7.a	English Language	8	8	33.0200	0.5092
2.C.8.a	Public Safety and Security	7	7	25.9025	0.5000
2.C.3.a	Computers and Electronics	7	7	21.7948	0.4955
2.C.1.b	Clerical	6	6	17.7187	0.4911
2.C.4.a	Mathematics	6	6	8.6635	0.4547
2.C.4.f	Sociology and Anthropology	5	5	11.6845	0.4846
2.C.5.b	Therapy and Counseling	4	4	8.0071	0.4643
2.C.1.a	Geography	2	2	0.7630	0.4234
2.C.4.g	Administration and Management	2	2	0.7249	0.4202
2.C.7.d	History and Archeology	2	2	0.6499	0.3961

The results in Table 3 and Figure 3 show the threshold values of K. The highest numerical values of C_{WD} and C_D were both 8, which was $\geq$3, while the highest numerical value of C_B was 33.0200 and that of C_C was 0.5092.

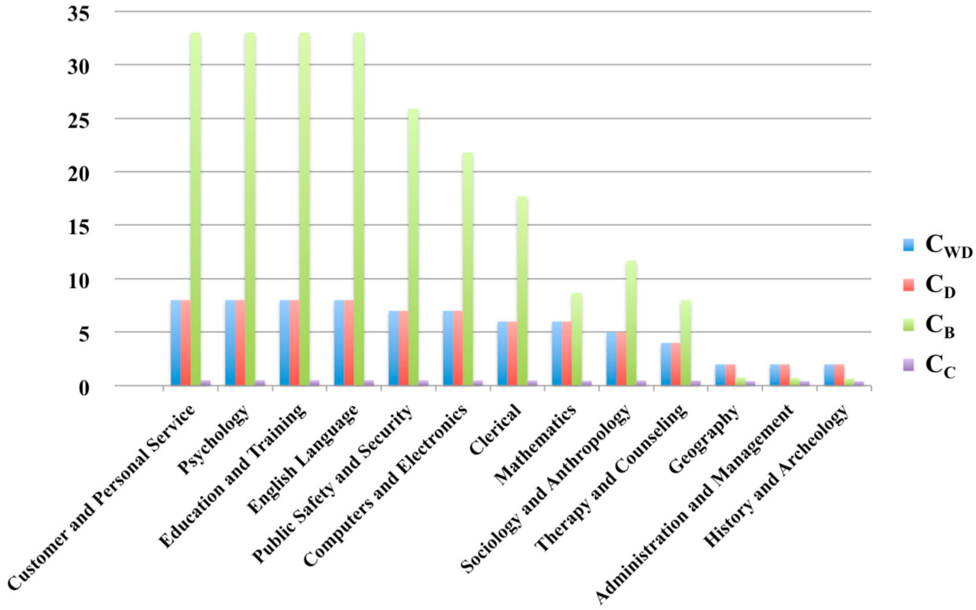

Figure 3. Histogram of the keyword numerical values of the centrality metrics for the knowledge characteristic.

4.2.2. Centrality Analysis of the Skills Characteristic

The keyword numerical values of the centrality metrics for the skills (S) characteristic are reported in Table 4, and the histogram is shown in Figure 4. The top 16 ECPC keywords in the O*NET database, from Reading Comprehension to Time Management, had the same C_{WD}, C_D, C_B, and C_C numerical value rankings and importance. However, the numerical values of C_{WD} and C_D for Systems Evaluation were less than those for Negotiation, and the numerical values of C_B and C_C for Systems Evaluation were greater than those for Negotiation. Moreover, the ranking of Mathematics for S was different from that of Mathematics for K.

Table 4. Keyword numerical values of the centrality metrics for the skills characteristic.

ECPC of O*NET-SOC		C_{WD}	C_D	C_B	C_C
2.A.1.a	Reading Comprehension	8	8	33.020004	0.509217
2.A.1.b	Active Listening	8	8	33.020004	0.509217
2.A.1.c	Writing	8	8	33.020004	0.509217
2.A.1.d	Speaking	8	8	33.020004	0.509217
2.A.2.a	Critical Thinking	8	8	33.020004	0.509217
2.A.2.b	Active Learning	8	8	33.020004	0.509217
2.A.2.c	Learning Strategies	8	8	33.020004	0.509217
2.A.2.d	Monitoring	8	8	33.020004	0.509217
2.B.1.a	Social Perceptiveness	8	8	33.020004	0.509217
2.B.1.b	Coordination	8	8	33.020004	0.509217
2.B.1.c	Persuasion	8	8	33.020004	0.509217
2.B.1.e	Instructing	8	8	33.020004	0.509217
2.B.1.f	Service Orientation	8	8	33.020004	0.509217
2.B.2.i	Complex Problem Solving	8	8	33.020004	0.509217
2.B.4.e	Judgment and Decision Making	8	8	33.020004	0.509217
2.B.5.a	Time Management	8	8	33.020004	0.509217
2.B.1.d	Negotiation	6	6	8.663457	0.454733
2.B.4.h	Systems Evaluation	5	5	9.875784	0.458506
2.B.4.g	Systems Analysis	4	4	7.845727	0.454733
2.B.5.d	Management of Personnel Resources	3	3	1.547893	0.431641
2.A.1.e	Mathematics	1	1	0	0.370805

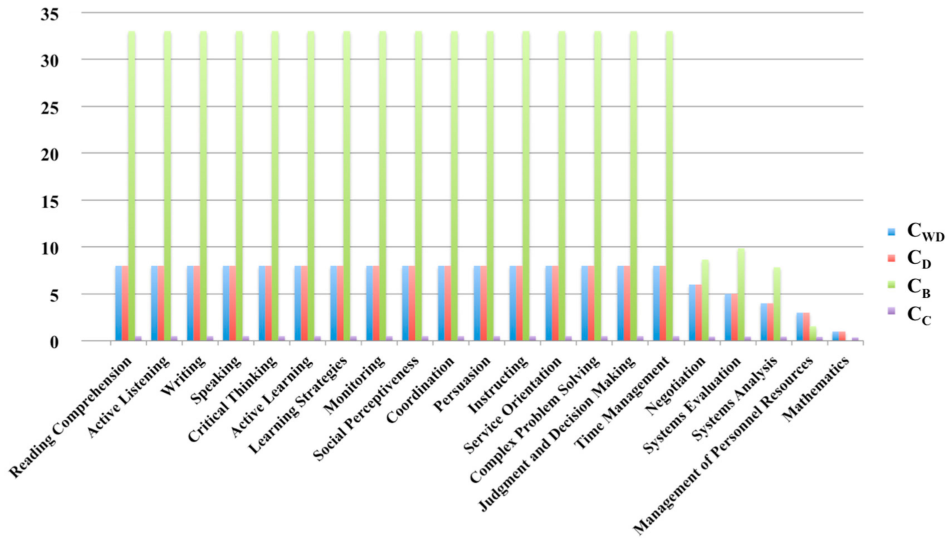

Figure 4. Histogram of the keyword numerical values of the centrality metrics for the skills characteristic.

The results in Table 4 and Figure 4 show the threshold values of S. The numerical values of all the keywords, except Mathematics, for C_{WD} and C_D were $\geq$3, while the highest numerical value for C_B was 33.020004, and for C_C it was 0.509217.

4.2.3. Centrality Analysis of the Abilities Characteristic

The keyword numerical values of the centrality metrics of the abilities (A) characteristic are reported in Table 5, and the histogram is shown in Figure 5. The top 12 ECPC keywords in the O*NET database, from Oral Comprehension to Speech Clarity, had the same C_{WD}, C_D, C_B, and C_C numerical value rankings and importance. Moreover, the numerical values of C_{WD} and C_D for Originality were equal to Category Flexibility and Selective Attention, while the numerical values of C_B and C_C for Originality were less than those for Category Flexibility and Selective Attention; thus, Originality was less important in the ECPC KCN. The numerical values of C_{WD} and C_D for Time Sharing were equal to those for Flexibility of Closure, the numerical value of C_B for Time Sharing was greater than that for Flexibility of Closure, and the numerical value of C_C for Time Sharing was less than that for Flexibility of Closure, so Time Sharing had a better ability to control the other nodes compared with Flexibility of Closure, while Flexibility of Closure had a better proximity between its node and the other nodes in the network compared with Time Sharing.

Table 5. Keyword numerical values of the centrality metrics for the abilities characteristic.

ECPC of O*NET-SOC		C_{WD}	C_D	C_B	C_C
1.A.1.a.1	Oral Comprehension	8	8	33.020004	0.509217
1.A.1.a.2	Written Comprehension	8	8	33.020004	0.509217
1.A.1.a.3	Oral Expression	8	8	33.020004	0.509217
1.A.1.a.4	Written Expression	8	8	33.020004	0.509217
1.A.1.b.1	Fluency of Ideas	8	8	33.020004	0.509217
1.A.1.b.3	Problem Sensitivity	8	8	33.020004	0.509217
1.A.1.b.4	Deductive Reasoning	8	8	33.020004	0.509217
1.A.1.b.5	Inductive Reasoning	8	8	33.020004	0.509217
1.A.1.b.6	Information Ordering	8	8	33.020004	0.509217
1.A.4.a.1	Near Vision	8	8	33.020004	0.509217
1.A.4.b.4	Speech Recognition	8	8	33.020004	0.509217
1.A.4.b.5	Speech Clarity	8	8	33.020004	0.509217
1.A.1.b.7	Category Flexibility	7	7	21.794843	0.495516
1.A.1.g.1	Selective Attention	7	7	21.794843	0.495516
1.A.1.b.2	Originality	7	7	17.538790	0.474249
1.A.4.a.2	Far Vision	4	4	7.342138	0.460417
1.A.1.g.2	Time Sharing	3	3	3.415597	0.421756
1.A.1.e.2	Flexibility of Closure	3	3	2.820284	0.445565
1.A.1.c.1	Mathematical Reasoning	2	2	0.466588	0.389085
1.A.1.d.1	Memorization	2	2	0.466588	0.389085

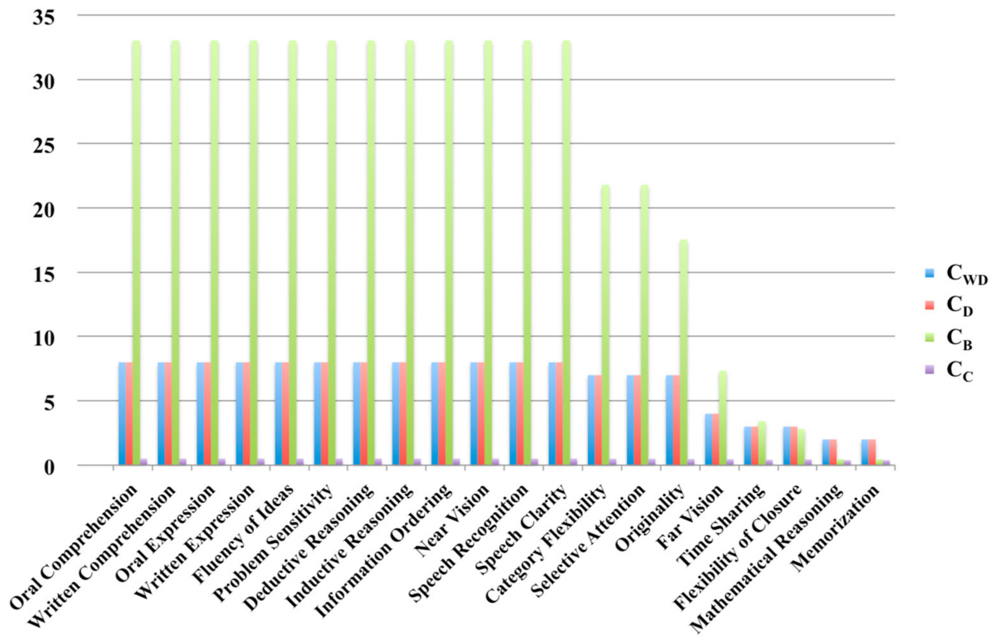

Figure 5. Histogram of the keyword numerical values of the centrality metrics for the abilities characteristic.

The results in Table 5 and Figure 5 show the threshold values of the A characteristic. The numerical values of C_{WD} and C_D were $\geq$3 for all the keywords, except Mathematical Reasoning and Memorization, while the highest numerical value of C_B was 33.020004, and for "C_C" it was 0.509217.

4.2.4. Centrality Analysis of the Technology Skills Characteristic

The keyword numerical values of the centrality metrics for the technology skills (TSs) characteristic are reported in Table 6, and the histogram is shown in Figure 6. The highest ranking ECPC keywords in the O*NET database for C_{WD} were greater than those of C_D, which indicated that because the C_{WD} rankings were greater than those of C_D, overlapping edges existed between the nodes and they needed to be weighted. Of the top five ECPC keywords, from Computer-based Training Software at the top to Spreadsheet Software, the numerical values were all the same within each column of C_D, C_B, and C_C, but because the numerical values of C_{WD} were greater than those of C_D, the priority ranking for C_{WD} was reordered. The numerical values of C_D for Presentation Software and Database User Interface and Query Software were the same, the numerical values of C_B and C_C for Presentation Software were less than those for Database User Interface and Query Software, and the numerical value of C_{WD} for Presentation Software was greater than that of C_D. Therefore, Presentation Software had a higher priority ranking. The inferences and implications of these results and data are shown in Table 6.

Table 6. Keyword numerical values of the centrality metrics for the technology skills characteristic.

ECPC of O*NET-SOC		C_{WD}	C_D	C_B	C_C
43232502	Computer-based training software	30	8	33.020004	0.509217
43232104	Word processing software	12	8	33.020004	0.509217
43233501	Electronic mail software	12	8	33.020004	0.509217
43231513	Office suite software	11	8	33.020004	0.509217
43232110	Spreadsheet software	8	8	33.020004	0.509217
43232106	Presentation software	10	7	21.794843	0.495516
43232306	Data base user interface and query software	8	7	29.027354	0.506881
43232103	Video creation and editing software	13	6	14.598498	0.472222
43232505	Multi-media educational software	12	6	11.362137	0.466245
43231507	Project management software	10	6	14.598498	0.472222
43232705	Internet browser software	6	6	18.448590	0.493304
43232702	Desktop communications software	11	4	4.494841	0.418561
43232102	Graphics or photo imaging software	6	4	10.604108	0.486784
43233502	Video conferencing software	5	4	5.091427	0.420152
43233405	Device drivers or system software	6	3	5.638575	0.452869
43232605	Analytical or scientific software	3	2	0.183126	0.379725
43232107	Web page creation and editing software	2	2	0.724854	0.420152
43232503	Spell checkers	2	2	0.105703	0.407749
43233004	Operating system software	2	2	0.555250	0.413858
43233413	Voice recognition software	2	2	0.105703	0.407749
43232402	Development environment software	2	1	0	0.361111
43232112	Desktop publishing software	1	1	0	0.398917
43232202	Document management software	1	1	0	0.398917
43233509	Mobile messaging service software	1	1	0	0.329851

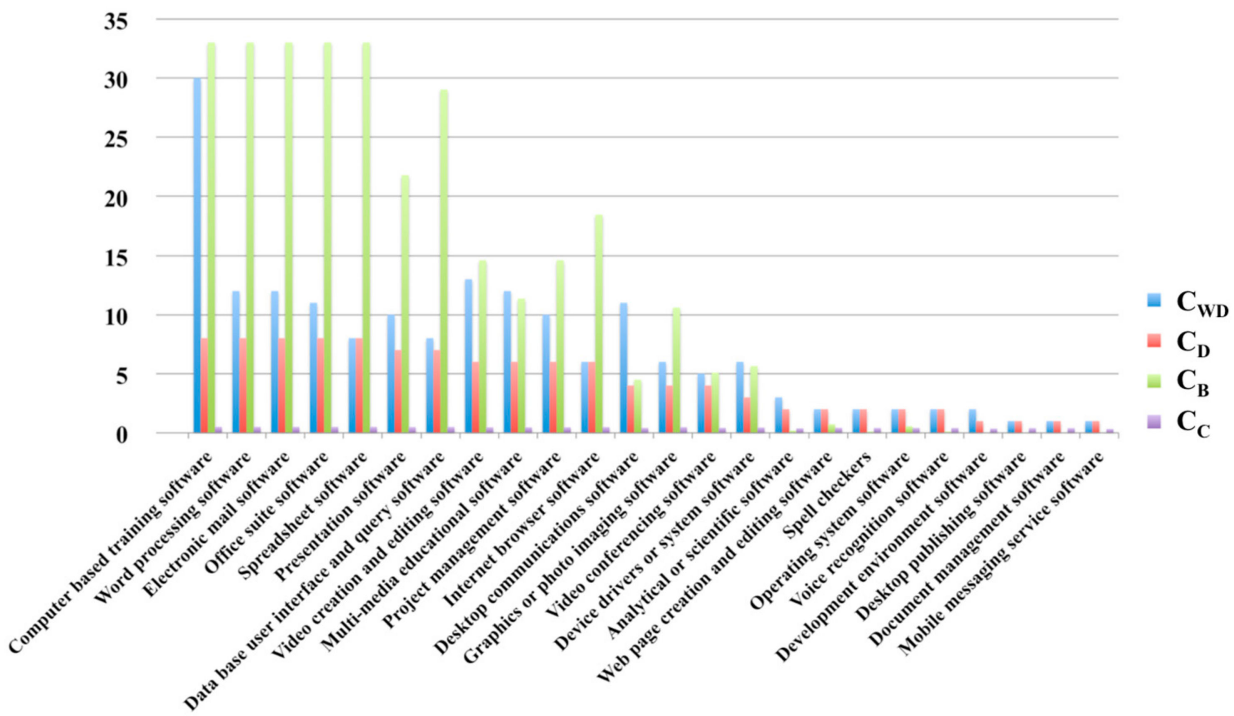

Figure 6. Histogram of the keyword numerical values of the centrality metrics for the technology skills characteristic.

The results in Table 6 and Figure 6 show the threshold values of the TSs characteristic. Most of the numerical values of C_{WD} and C_D were ≥ 3 (for C_{WD}, about half were ≥ 8, with the highest numerical value of 30), the highest numerical value for C_B was 33.020004, and for C_C it was 0.509217.

4.2.5. Centrality Analysis of the Technology Tools Characteristic

The keyword numerical values of the centrality metrics for the technology tools (TTs) characteristic are reported in Table 7, and the histogram is shown in Figure 7. Of the ECPC keywords found in the O*NET database, not all the numerical values of C_{WD} and C_D were equal as more C_{WD} values were greater than those of C_D, which indicated that overlapping edges existed between nodes and they needed to be weighted. Desktop Computers and Personal Computers had equal numerical values for C_{WD}, C_D, C_B, and C_C, resulting in the same ranking and importance. Four of the ECPC keywords, from Notebook Computers to Children's Science Kits, had the same values for C_{WD}, C_D, C_B, and C_C, resulting in the same ranking and importance. Of these four keywords, C_{WD} and C_D had the same numerical values for Photocopiers and the numerical values of C_B and C_C were greater; therefore, Photocopiers had a higher priority ranking compared with the other three keywords. The inferences and implications of these results are shown in Table 7.

Table 7. Keyword numerical values of the centrality metrics for the technology tools characteristic.

	ECPC of O*NET-SOC	C_{WD}	C_D	C_B	C_C
43211507	Desktop computers	8	8	33.020004	0.509217
43211508	Personal computers	8	8	33.020004	0.509217
44101501	Photocopiers	7	7	29.027354	0.506881
43211503	Notebook computers	7	7	21.794843	0.495516
43212105	Laser printers	7	7	21.794843	0.495516
52161529	Video cassette players or recorders	7	7	21.794843	0.495516
60141009	Children's science kits	7	7	21.794843	0.495516
52161505	Televisions	6	6	8.663457	0.454733
43211903	Touch screen monitors	8	5	12.590778	0.476293
44102801	Laminators	5	5	12.923891	0.480435
41111709	Binocular light compound microscopes	5	5	6.369563	0.451020
44111803	Compasses (pencil compasses)	5	5	6.369563	0.451020
42172001	Emergency medical services first aid kits	4	4	12.425484	0.474249
43211711	Scanners (reading pens)	4	4	8.702151	0.466245
60141006	Building blocks	4	4	7.496165	0.431641
60141102	Board games	4	4	7.496165	0.431641
52161502	Cassette players or recorders	4	4	4.150819	0.442000
41102401	Gas burners	4	4	2.699593	0.429961
41102406	Laboratory hotplates	4	4	2.699593	0.429961
41121803	Laboratory beakers	4	4	2.699593	0.429961
41122407	Laboratory scalpels	4	4	2.699593	0.429961
45121515	Hand held camcorders or video cameras	4	4	2.699593	0.429961
45121516	Digital camcorders or video cameras	4	4	2.699593	0.429961
45121517	Document camera	4	4	2.699593	0.429961
46181504	Protective gloves	4	4	2.699593	0.429961
46181804	Goggles (safety goggles)	4	4	2.699593	0.429961
43211708	Computer mouse or trackballs	7	3	5.638575	0.452869
42211701	Adaptive communication switches for the physically challenged	6	3	5.638575	0.452869
43211705	Game pads or joy sticks	6	3	5.638575	0.452869
60124508	Sand or water tables or activity centers	6	3	4.048586	0.415414
42211702	Braille devices for the physically challenged	5	3	5.638575	0.452869
42211706	Letter or symbol boards for the physically challenged	5	3	5.638575	0.452869
42192210	Wheelchairs	3	3	5.638575	0.452869
42212110	Page turners for the physically challenged	3	3	5.638575	0.452869
43211706	Keyboards (alternative computer keyboards)	3	3	5.638575	0.452869
45111607	Overhead projectors	3	3	3.415597	0.421756
45121504	Digital cameras	3	3	1.906135	0.387719
52161515	Compact disk players or recorders	3	3	1.906135	0.387719
60124514	Tactile toys	3	3	1.906135	0.387719
45111609	Multimedia projectors	3	3	1.537978	0.426641
45111614	Liquid crystal display projector	3	3	1.537978	0.426641

The results in Table 7 and Figure 7 show the threshold values of the TTs characteristic. The numerical values of C_{WD} and C_D were all ≥ 3 (the highest for both was 8), the highest numerical value for C_B was 33.020004, and for C_C it was 0.509217.

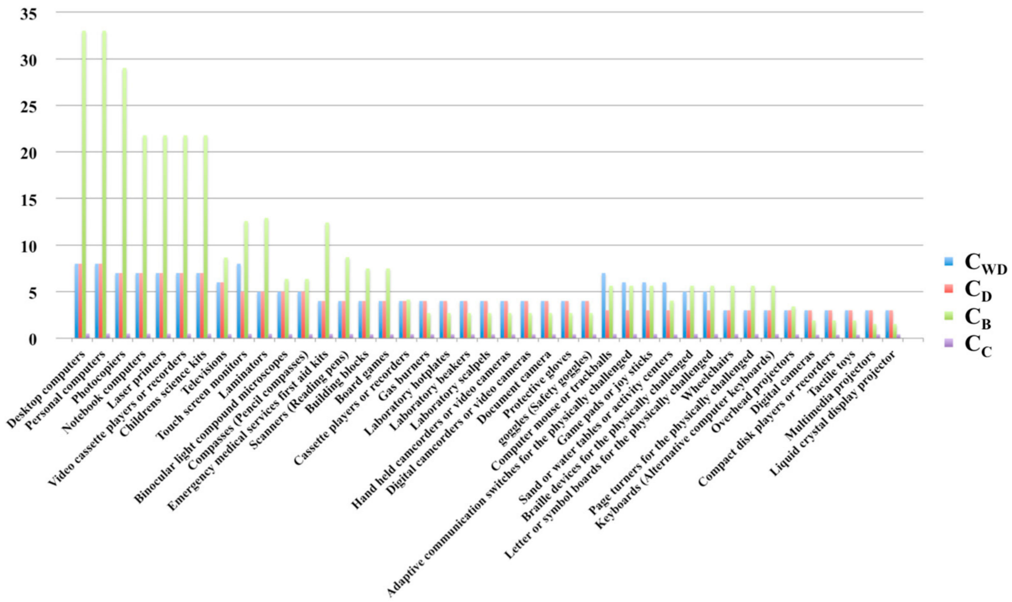

Figure 7. Histogram of the keyword numerical values of the centrality metrics for the technology tools characteristic.

4.2.6. Centrality Analysis of the Work Activities Characteristic

The keyword numerical values of the centrality metrics for the work activities (WAs) characteristic are reported in Table 8, and the histogram is shown in Figure 8. The top 17 ECPC keywords, from Getting Information to Coaching and Developing Others, in the O*NET database for C_{WD}, C_D, C_B, and C_C, were all equal and thus had the same ranking and importance. The inferences and implications of these results are shown in Table 8.

Table 8. Keyword numerical values of the centrality metrics for the work activities characteristic.

	ECPC of O*NET-SOC	C_{WD}	C_D	C_B	C_C
4.A.1.a.1	Getting Information	8	8	33.020004	0.509217
4.A.1.a.2	Monitor Processes, Materials, or Surroundings	8	8	33.020004	0.509217
4.A.1.b.1	Identifying Objects, Actions, and Events	8	8	33.020004	0.509217
4.A.2.a.3	Evaluating Information to Determine Compliance with Standards	8	8	33.020004	0.509217
4.A.2.b.1	Making Decisions and Solving Problems	8	8	33.020004	0.509217
4.A.2.b.2	Thinking Creatively	8	8	33.020004	0.509217
4.A.2.b.4	Developing Objectives and Strategies	8	8	33.020004	0.509217
4.A.2.b.5	Scheduling Work and Activities	8	8	33.020004	0.509217
4.A.2.b.6	Organizing, Planning, and Prioritizing Work	8	8	33.020004	0.509217
4.A.3.b.6	Documenting/Recording Information	8	8	33.020004	0.509217
4.A.4.a.2	Communicating with Supervisors, Peers, or Subordinates	8	8	33.020004	0.509217
4.A.4.a.4	Establishing and Maintaining Interpersonal Relationships	8	8	33.020004	0.509217
4.A.4.a.5	Assisting and Caring for Others	8	8	33.020004	0.509217
4.A.4.a.7	Resolving Conflicts and Negotiating with Others	8	8	33.020004	0.509217
4.A.4.b.2	Developing and Building Teams	8	8	33.020004	0.509217
4.A.4.b.3	Training and Teaching Others	8	8	33.020004	0.509217
4.A.4.b.5	Coaching and Developing Others	8	8	33.020004	0.509217
4.A.2.a.2	Processing Information	7	7	21.794843	0.495516
4.A.2.a.4	Analyzing Data or Information	7	7	21.794843	0.495516
4.A.2.b.3	Updating and Using Relevant Knowledge	7	7	21.794843	0.495516
4.A.3.b.1	Interacting With Computers	7	7	21.794843	0.495516
4.A.4.a.1	Interpreting the Meaning of Information for Others	7	7	21.794843	0.495516
4.A.4.a.3	Communicating with Persons Outside Organization	7	7	21.794843	0.495516
4.A.4.b.1	Coordinating the Work and Activities of Others	7	7	21.794843	0.495516
4.A.2.a.1	Judging the Qualities of Things, Services, or People	6	6	18.448590	0.493304
4.A.4.b.4	Guiding, Directing, and Motivating Subordinates	6	6	8.663457	0.454733
4.A.4.a.8	Performing for or Working Directly with the Public	5	5	12.923891	0.480435
4.A.4.c.1	Performing Administrative Activities	4	4	8.702151	0.466245

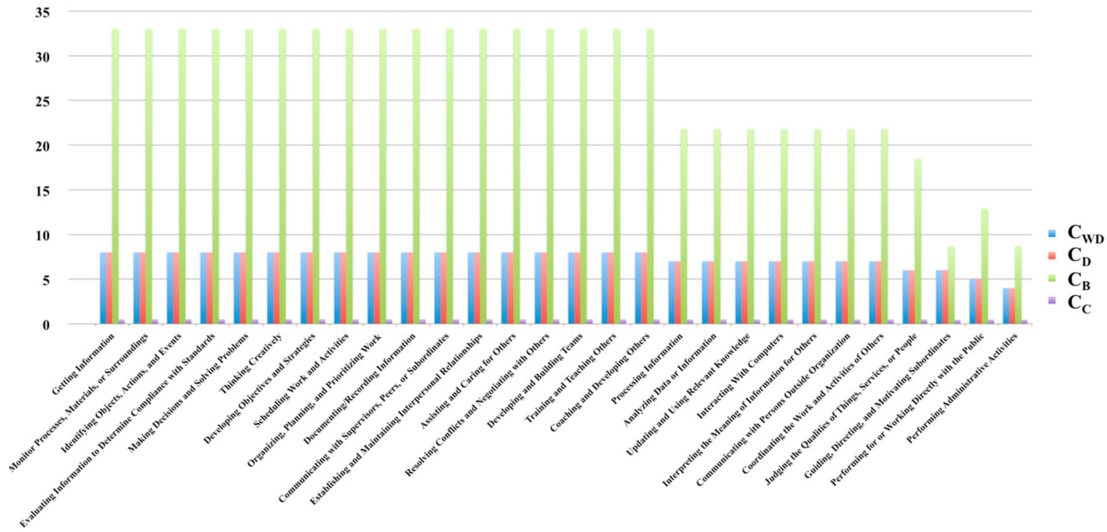

Figure 8. Histogram of the keyword numerical values of the centrality metrics for the work activities characteristic.

The results in Table 8 and Figure 8 show the threshold values for the WAs characteristic. The numerical values of C_{WD} and C_D were all $\geq$3 (the highest values for both was 8), the highest numerical value for C_B was 33.020004, and for C_C it was 0.509217.

4.2.7. Centrality Analysis of the Work Context Characteristic

The keyword numerical values of the centrality metrics for the work context (WC) characteristic are reported in Table 9, and the histogram is shown in Figure 9. The top 15 ECPC keywords in the O*NET database, from Letters and Memos to Time Pressure, all had the same values in each C_{WD}, C_D, C_B, and C_C column, resulting in the same ranking and importance. The inferences and implications of these results are shown in Table 9.

Table 9. Keyword numerical values of the centrality metrics for the work context characteristic.

	ECPC of O*NET-SOC	C_{WD}	C_D	C_B	C_C
4.C.1.a.2.j	Letters and Memos	8	8	33.020004	0.509217
4.C.1.a.2.l	Face-to-Face Discussions	8	8	33.020004	0.509217
4.C.1.a.4	Contact With Others	8	8	33.020004	0.509217
4.C.1.b.1.e	Work With Work Group or Team	8	8	33.020004	0.509217
4.C.1.b.1.g	Coordinate or Lead Others	8	8	33.020004	0.509217
4.C.2.a.1.a	Indoors, Environmentally Controlled	8	8	33.020004	0.509217
4.C.2.a.3	Physical Proximity	8	8	33.020004	0.509217
4.C.2.b.1.a	Sounds, Noise Levels Are Distracting or Uncomfortable	8	8	33.020004	0.509217
4.C.2.d.1.b	Spend Time Standing	8	8	33.020004	0.509217
4.C.3.a.2.a	Impact of Decisions on Co-workers or Company Results	8	8	33.020004	0.509217
4.C.3.a.2.b	Frequency of Decision Making	8	8	33.020004	0.509217
4.C.3.a.4	Freedom to Make Decisions	8	8	33.020004	0.509217
4.C.3.b.4	Importance of Being Exact or Accurate	8	8	33.020004	0.509217
4.C.3.b.8	Structured versus Unstructured Work	8	8	33.020004	0.509217
4.C.3.d.1	Time Pressure	8	8	33.020004	0.509217
4.C.1.a.2.f	Telephone	7	7	21.794843	0.495516
4.C.1.a.2.h	Electronic Mail	7	7	21.794843	0.495516
4.C.3.d.8	Duration of Typical Work Week	7	7	21.794843	0.495516
4.C.1.b.1.f	Deal With External Customers	7	7	17.538790	0.474249
4.C.1.d.1	Frequency of Conflict Situations	7	7	17.538790	0.474249
4.C.1.c.1	Responsible for Others' Health and Safety	6	6	24.105974	0.502273
4.C.1.d.2	Deal With Unpleasant or Angry People	6	6	14.598498	0.472222
4.C.1.a.2.c	Public Speaking	6	6	8.663457	0.454733
4.C.2.c.1.b	Exposed to Disease or Infections	5	5	13.813115	0.482533
4.C.1.c.2	Responsibility for Outcomes and Results	4	4	9.344077	0.468220
4.C.2.d.1.d	Spend Time Walking and Running	4	4	5.496837	0.445565

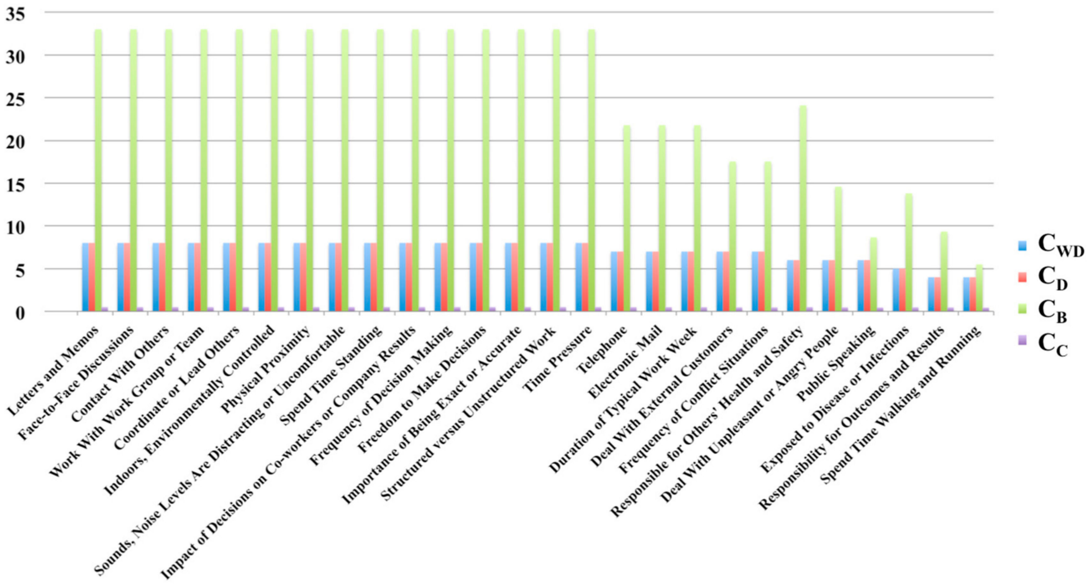

Figure 9. Histogram of the keyword numerical values of the centrality metrics for the work context characteristic.

The results in Table 9 and Figure 9 show the threshold values of the WC characteristic. All the numerical values of C_{WD} and C_D were ≥3 (the highest numerical value for both was 8), the highest numerical value for C_B was 33.020004, and for C_C it was 0.509217.

4.3. Network Visualization

The visualization of the centrality metrics for C_{WD} in the ECPC KCN shown in Figure 10 is represented by color-coded nodes and edges. For example, the purple nodes all corresponded to the numerical value of 8, with a percentage of 31.08, which was the largest proportion of all the nodes; the green nodes all corresponded to the numerical value of 2, with a percentage of 12.61, which was the second largest proportion of all the nodes; and the cyan nodes all corresponded to the numerical value of 1, with a percentage of 12.16, which was the third largest proportion of all the nodes.

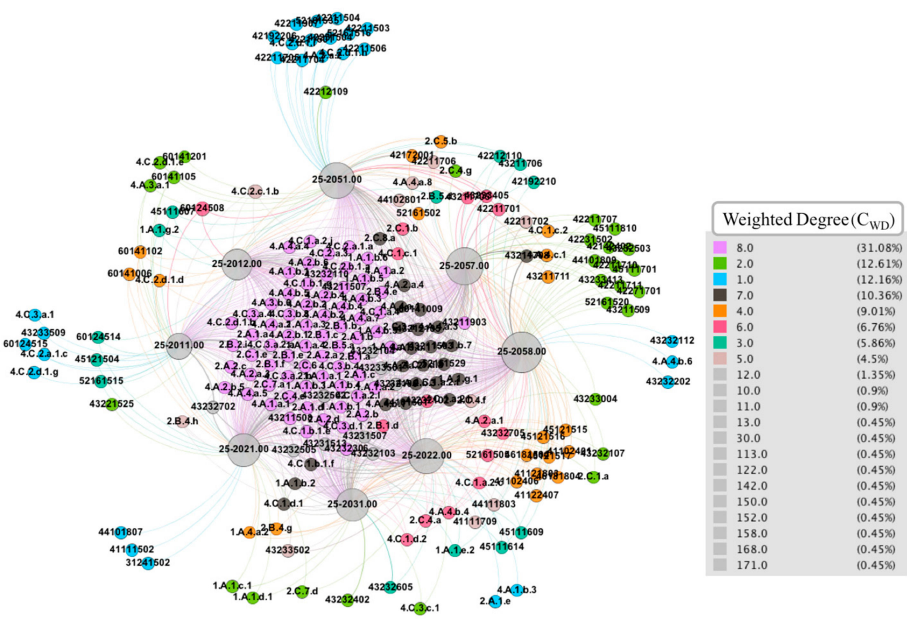

Figure 10. Visualization of the centrality metrics for C_{WD} in the ECPC KCN.

According to the results, starting with a percentage of 100 minus the numerical value of 2 for C_{WD} and its percentage of 12.61, and minus the numerical value of 1 for C_{WD} and its percentage of 12.16, the amount equaled 75.23%, which means that the nodes for C_{WD} were $\geq$3 and its percentage was 75.23%.

The visualization of the centrality metrics for C_D in the ECPC KCN shown in Figure 11 is represented by color-coded nodes and edges. For example, the purple nodes all corresponded to the numerical value of 8, with a percentage of 31.98, which was the largest proportion of all the nodes; the green nodes all corresponded to the numerical value of 1, with a percentage value of 13.06, which was the second largest proportion of all the nodes; and the cyan nodes all corresponded to the numerical value of 2, with a percentage of 12.16, which was the third largest proportion of all the nodes.

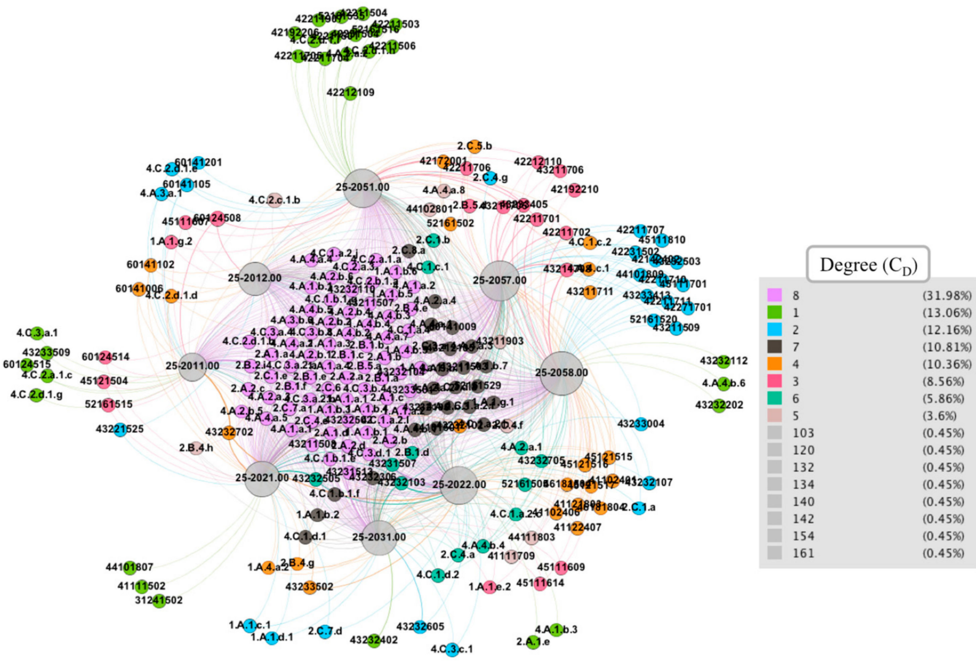

Figure 11. Visualization of the centrality metrics for C_D in the ECPC KCN.

According to the results, starting with a percentage of 100 minus the numerical value of 1 for C_D and its percentage of 13.06, and minus the numerical value of 2 for C_D and its percentage of 12.16, the amount equaled 74.78%, which means that the nodes for C_D were $\geq$3 and its percentage was 74.78%.

The visualization of the centrality metrics for C_B in the ECPC KCN shown in Figure 12 is represented by color-coded nodes and edges. For example, the purple nodes all corresponded to the numerical value of 33.020004, with a percentage of 31.98, which was the largest proportion of all the nodes; the green nodes all corresponded to the numerical value of 0.0, with a percentage of 13.06, which was the second largest proportion of all the nodes; and the cyan nodes all corresponded to the numerical value of 21.794843, with a percentage value of 8.11, which was the third largest proportion of all the nodes. Therefore, the purple nodes (all with a maximum numerical value of 33.020004) as the central nodes all had more flows of multidisciplinary knowledge to share with the other nodes in the ECPC KCN.

The visualization of the centrality metrics for C_C in the ECPC KCN shown in Figure 13 is represented by color-coded nodes and edges. For example, the purple nodes all corresponded to the numerical value of 0.509217, with a percentage of 31.98, which was the largest proportion of all the nodes; the green nodes all corresponded to the numerical value of 0.495516, with a percentage of 8.11, which was the second largest proportion of all the nodes; and the cyan nodes all corresponded to the numerical value of 0.373311, with a percentage of 7.21, which was the third largest proportion of all the nodes. Therefore, the purple nodes (all with a maximum numerical value of 0.509217) had faster and easier access to the spread of information and communication to the other nodes in the ECPC KCN.

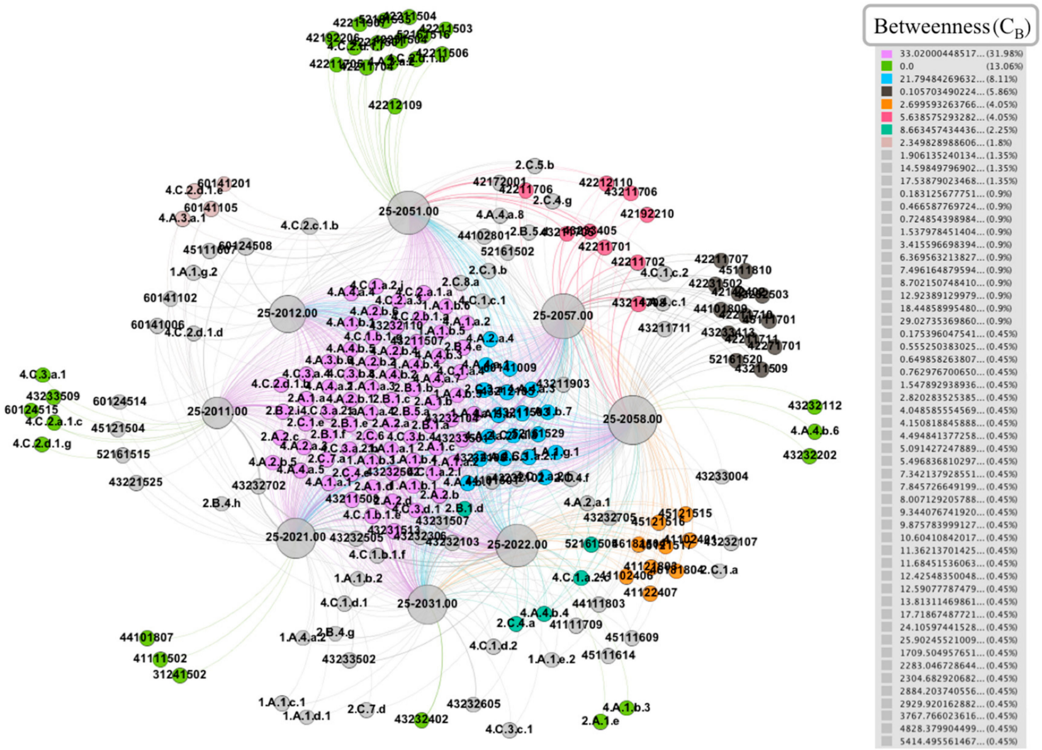

Figure 12. Visualization of the centrality metrics for C_B in the ECPC KCN.

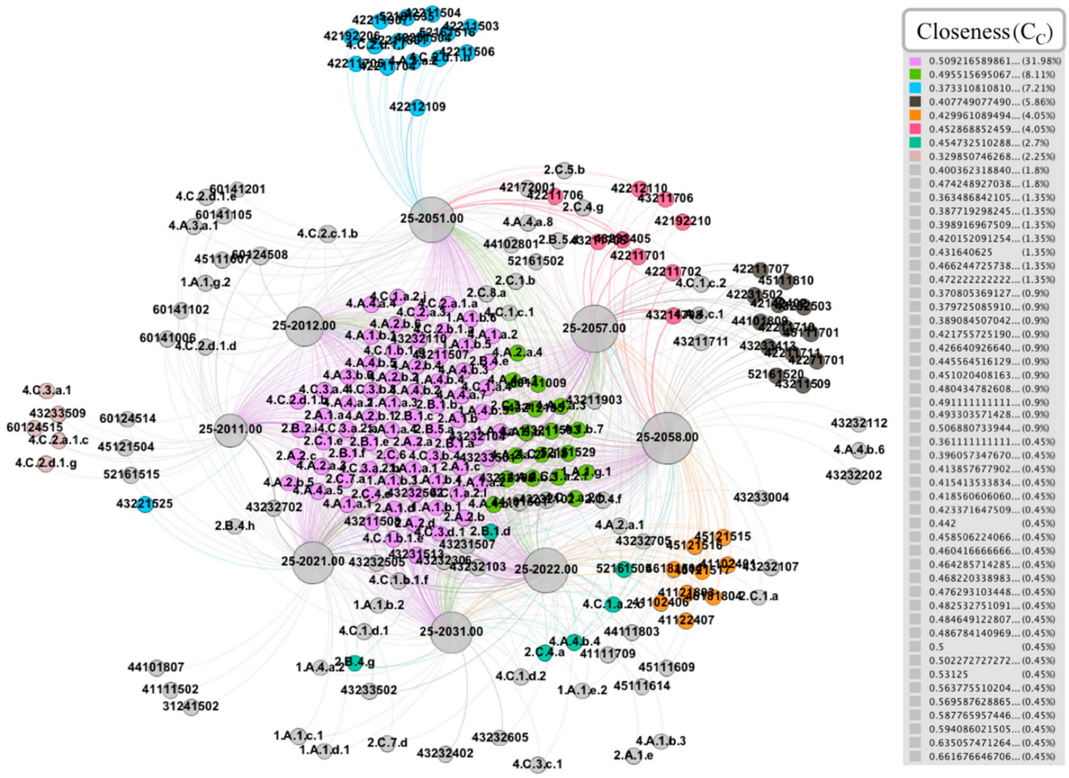

Figure 13. Visualization of the centrality metrics for C_C in the ECPC KCN.

5. Discussion

From the results shown in Figures 10 and 11, which displayed the visualization of the centrality metrics of C_{WD} and C_D in the ECPC KCN, for all eight categories of educational professionals (according to the occupational titles in O*NET), at least 75.23% and 74.78% of ECPC keyword co-occurrence existed in more than three of the categories. The ranking and importance of the numerical values of C_{WD} and C_D [14], as represented by the characteristics of weighted co-occurrence and co-occurrence [18,25,26], respectively, were $\geq$3; therefore, they should be included in the e-learning curricula evaluation metrics for CB-TPD.

The results in Figure 12 show the visualization of the centrality metrics of C_B in the ECPC KCN. The highest numerical value of C_B was 33.020004, with a percentage of 31.98, which was the largest proportion of nodes and thus carried the most importance [14]; as such, its role was a mediator between nodes [30] or an intermediary for information transfer [34]. Since the highest numerical value of C_B represented 31.98% of the nodes, it should also be included in the e-learning curricula evaluation metrics for CB-TPD.

Similar results were found for the centrality metrics of C_C, the visualization of which is shown in Figure 13. With the highest numerical value of 0.509217 and percentage of 31.98 for C_C, this was the largest proportion of nodes and thus the most important [14], and its role was to spread information rapidly to all the other nodes. Because the highest numerical value of C_B represented 31.98% of the nodes, it should be included in the e-learning curricula evaluation metrics for CB-TPD. To sum up, using the SNA approach to obtain centrality metrics from the ECPC KCN to construct an evaluation framework for e-learning curricula evaluation metrics for CB-TPD and to verify its importance in the evaluation of e-learning curricula in the current study was in line with the research methods in previous studies [12,18].

Regarding the numerical values of the centrality metrics and the histograms for the TSs and TTs characteristics shown in Tables 6 and 7 and Figures 6 and 7, respectively, there were differences between the numerical values of C_{WD} and C_D in the ECPC KCN. For example, the numerical values of C_{WD} and C_D for Computer-based Training Software (Commodity Code: 43232502) was 30 and 8, respectively, as presented in Table 6. Discussing this finding in more detail, for Computer-based Training Software, the TSs characteristics of the ECPC keywords in O*NET consisted of nine sub-ECPC keywords, including Appletree, Children's Educational Software, Common Curriculum, EasyCBM, Instructional Software, Moodle, Padlet, Schoology, and Text to Speech Software. In another example, the numerical values of C_{WD} and C_D for Touchscreen Monitors (Commodity Code: 43211903) were 8 and 5, respectively, as presented in Table 7. Discussing this finding in more detail, for Touchscreen Monitors, the TTs characteristic of the ECPC keywords in O*NET consisted of two sub-ECPC keywords, including Interactive Whiteboards and Wireless Touchscreen Monitors. The results in the previous examples show that the ECPC keywords could be broken down into sub-keywords based on the centrality metrics of C_{WD} and C_D and the attributes of the KSAOs. This framework provided a more detailed top-down hierarchy of evaluation metrics compared with other evaluation frameworks for e-learning curricula evaluation metrics for CB-TPD.

Regarding the numerical values of C_{WD} and C_D for the TSs and TTs characteristics categorized by O*NET, the results of the SNA for both metrics were not equal as the numerical values of C_{WD} were greater than those of C_D in the ECPC KCN. These results directly influenced those of the numerical values of C_B and C_C for the TSs and TTs characteristics, which were ranked differently. Moreover, the flows of knowledge and information in the curricula contents influenced each other, especially the higher numerical values of C_B, which had more flows of multidisciplinary knowledge, and the higher numerical values of C_C, the nodes of which were faster and easier to access and could spread information and communication with other nodes. These results prove that the nodes in the ECPC KCN were all connected to each other via edge relationships and they were all related to the connective relationship between their flows of knowledge and information in the e-learning curricula evaluation metrics for CB-TPD [40].

Because the kindergarten and elementary school special education teacher categories lacked complete data for these two occupations, the data collection of which is currently underway, they were not included in the existing scope of the research analysis. It is suggested that these two occupations be included in the centrality metrics and SNA data processing in the future after the O*NET database update has been completed, and then combined with the other eight educational professionals' occupational summary reports to construct a new KCN, which will more precisely and completely search for the attributes of the KSAOs and provide more ECPC keywords to develop e-learning curricula evaluation metrics for CB-TPD.

The ECPC keywords related to e-learning curricula development for CB-TPD found in the SNA in this study (see Tables 3–9 and Figures 3–9) mainly focused on online learning in the work context. All the ECPC keywords directly related to online learning curricula development can serve as a sustainable transition to online learning during uncertain times, such as the post-COVID-19 era and beyond.

Although this study also has some limitations, these do not invalidate the results obtained, indicating the need to focus on a clear trend of how to construct the e-learning curricula evaluation metrics for CB-TPD. This research uses the real data of the open governmental database to conduct complex network centrality analysis to construct the e-learning curricula evaluation metrics for CB-TPD. Since there is currently no complete real data, it cannot be used to conduct network-centric research to construct relevant curricula evaluation metrics for a widely studied field of research, such as recent related research in the training of university professors [41].

This study is different from using the questionnaire survey methods of SEM (including exploratory factor analysis and confirmatory factor analysis) [42], AHP method multi-attribute decision making [43], and even documentary analysis/content analysis (through a descriptive and inferential analysis) [41,44] to construct e-learning curricula evaluation metrics for CB-TPD practice application.

Different from other research methods and approaches mentioned above, the pedagogical implications and significance of this research that more diversely uses real data to accurately find out e-learning curricula evaluation metrics. Due to the evolution and expansion of the database over time, this research method is also used for online teaching about longitudinal database/open government data and network visualization in future lines of research.

In this study, the research framework adopted the O*NET KSAOs model and its original investigation framework from competency-based concepts to survey and measure competency in TPD, which is also different from other research. Referring to past research, related field researchers stated the importance of the framework of Education 4.0 and teacher skills [44], and also supplied a systematic literature review that referenced and discussed fifty-six study papers about framework approach for components of Education 4.0 in Industry 4.0 [45], stating that the theoretical framework can be used as reference and supplement in this study and in future lines of research.

Previous researches have used content analysis to conduct inferential analysis from eighty-seven publications; have qualitatively stated and described that an Education 4.0 teacher has technological skills, guidance skills, lifelong learning skills, and personal characteristics [44]; and have argued that conducting a systematic literature review in 21st century skills/competency frameworks with the Education 4.0 is necessary to develop teacher future skills/competency [45]. The above referenced teacher future skills/competency must be relative to this study, and, at the same time, must be the main important nodes/ECPC keywords in the ECPC KCN network.

6. Conclusions and Recommendations

This study used the SNA approach and Gephi software algorithms to describe the structural characteristics of the ECPC KCN (see Table 1); analyze the centrality metrics of C_{WD}, C_D, C_B, and C_C (see Tables 3–9 and Figures 3–9); and present the visualization of the ECPC KCN (see Figures 10–13). Through the step-by-step implementation of the above data processing, the threshold values were found to construct and optimize the evaluation metrics of e-learning curricula for CB-TPD. The following conclusion and education policy recommendations were drawn based on the results of the above analyses.

First, this study searched for the structural characteristics of the ECPC KCN and found that the sum of the existing edges was more than the number of nodes and edges, which clearly showed the different main categories and educational professionals occupational titles in O*NET OnLine and the different structural characteristics (such as the number of nodes and edges, the sum of existing edges, and network density) in the ECPC KCN. These findings will facilitate researchers' and education policy decision-makers' understanding of the phenomenon of the co-occurrence of ECPC keywords.

Second, the numerical values of C_{WD} were greater than or equal to those of C_D (meaning that weighted co-occurrence and co-occurrence existed simultaneously) regarding the TSs and TTs characteristics in the KSAOs. As shown in the visualization of the numerical values of C_{WD} and C_D, they were equal regarding the knowledge, skills, abilities, work activities, and work context characteristics of the KSAOs. These findings point to the importance of the centrality metrics of C_{WD} and C_D, respectively, as represented in the characteristics of the weighted co-occurrence and co-occurrence in the complete KCN.

Third, the findings from this study showed the practical educational implications of curriculum design and implementation through constructing e-learning curricula evaluation metrics for CB-TPD and verifying the importance of curricula evaluation. The results showed the threshold values of the numerical values of C_{WD} and C_D, which were $\geq$3, while the numerical value of C_B was 33.020004, with a percentage value of 31.98, and the numerical value of C_C was 0.509217, with a percentage value of 31.98. With these findings, curriculum designers and planners can use these threshold values to construct and optimize e-learning curricula evaluation metrics for CB-TPD.

Fourth, the visualization of the centrality metrics of C_{WD}, C_D, C_B, and C_C were color-coded to ease researchers' observation of relationship links (such as direct influences, knowledge flows, and information flows) between nodes and edges in the complete KCN. This method of using an intuitive visualization of a color-coded graph layout in Gephi to locate the relative geographical location of important nodes in a complete network, along with their numerical values and percentages, directly influenced the knowledge and information flows that existed between all the nodes in the ECPC KCN.

Fifth, the finding from this study obtained six of the ECPC keywords, from Customer and Personal Service to Computers and Electronics for the knowledge characteristic (see Table 3); sixteen of the ECPC keywords, from Reading Comprehension to Time Management for the skills characteristic (see Table 4); twelve of the ECPC keywords, from Oral Comprehension to Speech Clarity for the abilities characteristic (see Table 5); seven of the ECPC keywords, from Computer-Based Training Software to Data Base User Interface and Query Software for the technology skills characteristic (see Table 6); seven of the ECPC keywords, from Desktop Computers to Children's Science Kits for the technology tools characteristic (see Table 7); seventeen of the ECPC keywords, from Getting Information to Coaching and Developing Others for the work activities characteristic (see Table 8); and fifteen of the ECPC keywords, from Letters and Memos to Time Pressure for the work context characteristic (see Table 9). Thus, eighty of the main important nodes/the ECPC keywords were used in the ECPC KCN network in total; thus, these main important nodes could be the main evaluation metrics to construct e-learning curricula for CB-TPD.

In conclusion, the research results have proven that centrality metrics can quantify and evaluate the importance or influence of a specific object (i.e., nodes and edges) in the ECPC KCN related to e-learning curricula evaluation metrics for CB-TPD [25,26,28,29]. In the light of the research framework and procedures in this study, they will enable education practitioners and professionals, e-learning curriculum designers and developers, and education policy decision-makers to manifest structural network centrality metrics, structural relationships, and influence between nodes and edges to visualize abstract concepts and to explain the theoretical and practical implications of education-related occupational real Big Data (such as the O*NET OnLine database). Therefore, the results of this study can be used as evaluation metrics to construct e-learning curricula for CB-TPD and as a reference for conducting related academic research and cultivating educational professionals' online curricula, such as the practical applications of ECPC, integrated curricula design and the implementation of transdisciplinary programs, and teacher education.

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